A REPORT TO

THE SECRETARY OF THE AIR FORCE

C-130 Broad Area Review (BAR)

ADDENDUM

King 56 Salvage

An overview of the June/July 1998 salvage operation to include the collection and examination of selected wreckage relating to the scenarios laid out in the 15 January 1998 C-130 Broad Area Review Report.

25 August 1998 Addendum
to the 15 January 1998 Report

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Background

This report is a result of the Secretary of the Air Force directed C-130 Broad Area Review (BAR) recommendation to "recover selected wreckage from King 56." The components of greatest interest were: the wing section, the fuselage tanks, and the cockpit fuel quantity gauges. These items could answer many open questions and provide additional information concerning various fuel-related scenarios. While the exact cause of the King 56 mishap may never be known with absolute certainty, the benefits of wreckage recovery were:

(1) To confirm or refute 21* scenarios developed by the BAR team.
(2) To search for evidence that might point to an unknown new scenario.

While recovering wreckage, every attempt was made not to disturb human remains. The Operations Plan was clear on this point--"It is not the intent of the recovery operation to recover or disturb the remains of the crew and passenger of King 56."

21 Scenarios Proposed and Examined

The BAR team developed and examined 21* scenarios based upon theories of circumstances that could cause a C-130 to lose power to all four engines. As King 56 is only the second** recorded incident of four-engine flameout in almost 25 million worldwide C-130 flying hours, any scenario would be based upon an unusual sequence of events occurring. The team categorized 17 of these scenarios as "Not Likely" in view of available evidence at the time and four of these scenarios as "Likely."

The "Likely" scenarios, all caused by fuel starvation, were:

- Left Hand Auxiliary Fuel Tank Run Empty
- Right Hand Fuselage Fuel Tank Run Empty
- Insufficient Fuel Manifold Priming
- Right Hand Fuselage Fuel Tank Pump Failure

The only "Likely" scenario not refuted by wreckage recovery was Right Hand Fuselage Fuel Tank Run Empty

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* The original BAR report discussed scenarios 1 through 20, which included a "2a" and "2b". Additionally, another scenario was later added (identified as "21").

** After the original BAR report, a 35+-year-old incident was found on a C-130A model relating to an error made during the first installation of a modification involving the fire handles. When the touchdown relay was energized upon take-off, the fuel shut-off valves closed and the engines flamed out. The error was corrected on this aircraft and not repeated on any future modifications. This incident has no relevance to the King 56 mishap and is included here to insure the record is complete.

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The only "Not Likely" scenario not refuted by wreckage recovery was "Refuel/Dump Line Rupture" but based on extensive analysis the BAR team found this scenario to be highly improbable.

Evidence for Unknown New Scenario

A meticulous salvage operation was conducted that included C-130 technical experts integrated real-time into the salvage operation. This was done to gather information on the recovered parts. Any insight that pointed to an unknown new scenario was to be used as a decision point to reevaluate the scope of wreckage recovery. **There was no insight pointing to any new scenarios.**

Conclusion

Based upon evidence gathered during this salvage operation, the BAR team concluded:

King 56 engines stopped due to fuel starvation as a result of improper fuel management procedures. The crew failed to correctly analyze the situation in time to take the appropriate corrective actions.

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Section 1.0

Salvage Operation

1.1 Overview

The C-130 Broad Area Review Team was tasked to plan and oversee the salvage operation of King 56. The objective was twofold:

(1) To confirm or refute 21 scenarios developed by the BAR Team.
(2) To search for evidence that might point to an unknown new scenario.

A King 56 salvage operations plan was developed and briefed to the Acting Secretary of the Air Force, the Air Force Chief of Staff, and Senators Smith and Wyden prior to publication. The plan did not include the recovery of human remains; while recovering wreckage, every attempt was made not to disturb the remains.

The key elements of the salvage operation were:

(1) Assembling the appropriate resources
(2) Locating the wreckage
(3) Recovery
(4) Examination, preservation, and disposition of recovered items.

1.2 Resources

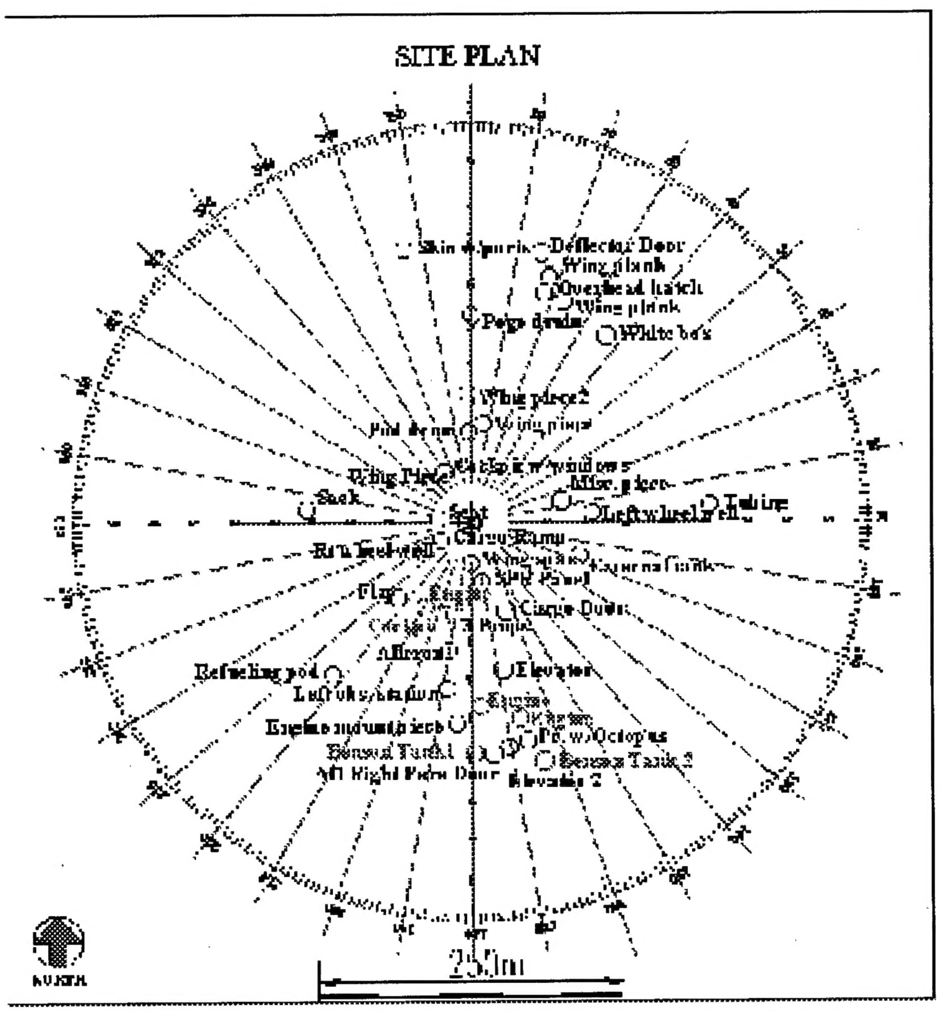
1.2.1 Recovery Team Members: The BAR Team organized a shipboard (recovery) team and a shore team to oversee the operation. Based on space limitations aboard the ship, the recovery team was limited to five individuals. These five individuals were handpicked for their expertise in accident investigation and knowledge of the C-130 aircraft. Their primary duties were to identify items of wreckage when viewed by video (at ocean depths in excess of 5,000 feet), define the recovery priorities on a real time basis, and finally to examine wreckage as it was recovered to determine if there was any evidence that pointed to new insight about the accident. The plan was to reevaluate the scope and focus of wreckage recovery if new insight was gained. The recovery team members and primary shore team members are listed in Table 1-1.

Recovery Team Commander	**Col William Kane**	**Special Assistant to the Commander 22AF**
Recovery Team Member	**Mr. George Anderson**	**NTSB**
Recovery Team Member	**Mr. Ron McGregor**	**HQ AFSC/SEF**
Recovery Team Member	**CMSgt Randy Wisener**	**HQ AMC/DOV**
Recovery Team Member	**MSgt David Hoyng**	**317th AG/QA**
Shore Team Leader	**Lt Col Dan Stanton**	**HQ AFSC/SEF**
Shore Team, Public Affairs	**Maj Dan Epright**	**US STRATCOM/J020**
Shore Team, Contracting	**TSgt John Peterson**	**60th CONS/LGCV**

Table 1-1 Recovery Team Members

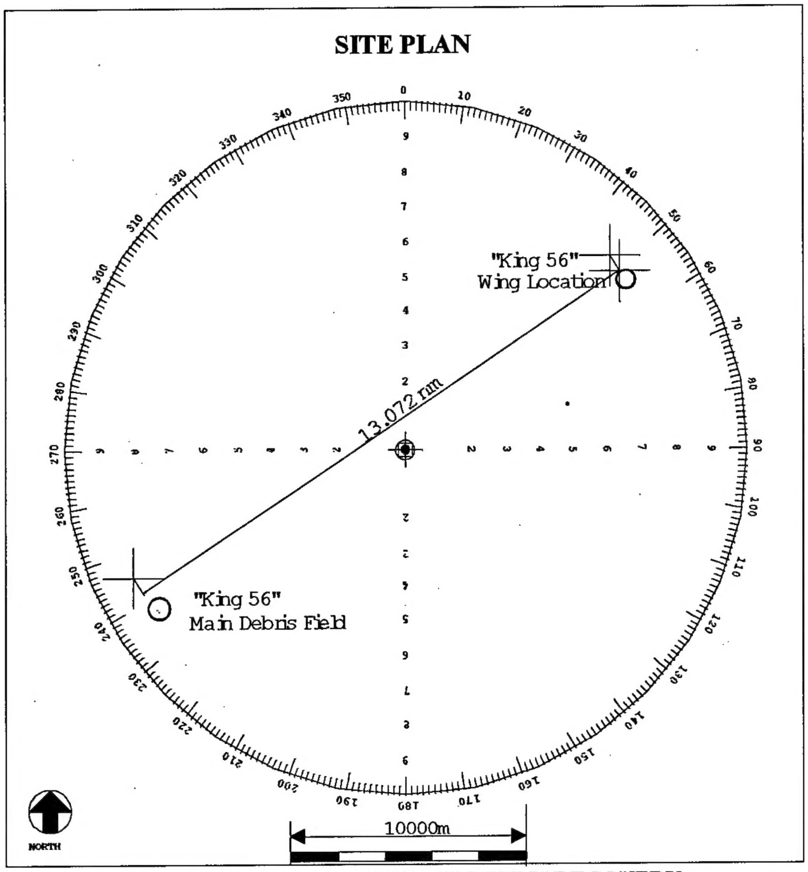
1.2.2 Navy Resources: The search and recovery ships, crews, and systems were provided by the US Navy Office of the Director of Ocean Engineering Supervisor of Salvage and Diving. The primary ship was the motor vessel (M/V) Independence, which was equipped with a deep drone video equipped remotely operated vehicle and a deep ocean salvage system. The support ship was the motor vessel (M/V) Auriga, which was equipped with a side scanning sonar system.

1.3 Locating the Wreckage: The location of the main body of wreckage (debris field) was certain but the location of a key piece of wreckage (approximately 55' of the wing) was uncertain. Shortly after King 56 crashed, the U.S. Coast Guard Cutter Buttonwood made an attempt to recover the wing. Despite valiant recovery efforts, the wing was lost. A considerable effort went into reviewing the Buttonwood's situation report and subsequently the detailed logs to define search areas after projecting a last known position for the wing. The M/V Independence found the main debris field at its expected location at a depth of 5,300 feet. The M/V Auriga conducted a search for the wing and finally located it at a depth of 3,200 feet approximately 13 miles from the main debris field. Figures 1-1 and 1-2 show the main debris field and location of the wing to main debris field.



US AIRFORCE C-130 "KING 56" DEBRIS RECOVERY

Figure 1-1



US AIR FORCE C-130 "KING 56" DEBRIS RECOVERY

Figure 1-2

1.4 Recovery: The M/V Independence was used to support the remotely operated vehicle (ROV), Deep Drone, and to provide direct lift capability. The ROV was used to survey the debris field; identify specific pieces of wreckage; and if appropriate, recover them. In some cases video analysis on the ocean floor was sufficient and parts were not recovered. Some of the wreckage of interest was brought to the surface by the ROV while large items were raised by the M/V Independence. The itemized list of recovered items can be found in the wreckage evaluation, Section 2.1 of this report.

1.5 Examination, Preservation, and Disposition of Recovered Items: Each piece of wreckage recovered was examined onboard ship for identification and evidence which could provide clues as to the cause of the King 56 mishap. The items were rinsed with fresh and/or deionized water and (if stored) stored in deionized water to minimize corrosion. The items were photographed, videotaped, and logged. Depending on the item and the skills required to perform further detailed examination, teardown, and analysis, a decision was made as to their disposition. Subsequent sections of the report summarize these evaluations. The depots and laboratories that performed the examination, teardown, and analysis are identified along with reference to their detailed report. A BAR team member was present at the analysis of critical components, including the engines, the temperature datum valves, the pumps, and the fuel gauges.

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Section 2.0

What the Wreckage Told Us

2.1 Investigation Fundamentals

2.1.1 Switch Positions: Although cockpit control panel switch positions were documented as each piece of wreckage was first observed on the deck of the M/V Independence, it is likely that some do not reflect either their actual position when the engines were flaming out or their position at the time of aircraft impact. It is probable that factors such as crew attempts to restart engines, impact forces, or the actual recovery of the panels themselves may have changed individual switch positions.

Although some switch positions may have been changed, it is believed that some switch positions are more likely to be accurate than others. Simple two position toggle switches are easily moved and may have been repositioned by the impact forces or by Deep Drone during the recovery efforts. Lever lock type toggle switches are less likely to have been moved during the crash or recovery effort because the toggle of these type switches must be lifted against spring pressure before the switch can be moved. Red guarded toggle switches (especially those that have the red guard safety wired in the closed position) are also less likely to have been moved during the recovery effort. Rotary switches with positive positions; such as the generator switches, inverter switches, and fuel crossfeed valve switches, are the most likely to reflect the actual switch positions at the time of impact.

In any case, the position of switches observed at an accident site must be considered fully before arriving at any conclusions. This is especially true in this case since the crew had over 16 minutes to attempt engine restarts and the Deep Drone recovery effort may have disturbed them as well.

2.1.2 Valve Positions: Valve positions were all carefully documented. They were visually inspected and physically verified. The position of fuel valves are important because, in the event of a complete electrical failure, they retain their final powered position. Specifically, the fuel system control valves are motor operated and receive power from the essential DC bus. Essential DC power was lost when the last engine driven generator ceased to supply power to the essential AC bus (The essential DC bus receives power from the essential AC bus through two transformer rectifier units). Therefore, these valve positions reflect their position when the last engine flamed out. If the final powered position of enough valves is determined, then it is probable that the tank supplying fuel when the flameouts occurred can be determined.

2.2 Wreckage Evaluation

The following items of wreckage, whose recovery and analysis speak directly to the cause of this mishap, are discussed in this section:

- Wing Section and Internal Components
- Fuel Control Panel

- Auxiliary Fuel Panel
- RH Fuselage Tank & Components
- LH Fuselage Tank & Components
- Engine Instrument Panel
- Engines and Engine Components

All other recovered items are discussed in Appendix A. Appendix B contains a summary of the depot and laboratory reports for those parts analyzed.

2.2.1 Wing Section. The wing section measured approximately 55 feet in length and consisted of the center wing box (i.e., left center wing station 220 to right center wing station 220) and a portion of the left outer wing from left outer wing station zero to approximately left outer wing station 214. This section of the wing contained approximately two feet of the #1 main tank, the #1 dry bay, the #2 main fuel tank, the #2 dry bay, the left auxiliary fuel tank, the center dry bay, the right auxiliary fuel tank, and a portion of the #3 dry bay. The leading and trailing edges were destroyed with only small amounts of structure/sheet metal still attached.

2.2.1.1 Number One Main Tank. Approximately two feet of the upper and lower wing structure which makes up the #1 fuel tank was present. The #1 fuel boost pump (P/N 60-369, S/N 123) was still attached. This pump was removed and visually examined. Nothing unusual was noted. It was then sent to the Air Force Research Lab's Materials Directorate (AFRL/MLS) at Wright-Patterson AFB for teardown and further analysis. In addition, samples of the charcoal-colored fire suppression foam (a.k.a. fuel foam) from this tank were sent to Aeronautical System Center, Flight Systems Engineering Division (ASC/ENF) for analysis. Nothing unusual was found with either the pump or the fuel foam.

2.2.1.2 Number One Dry Bay. A section of the front spar in the area of the #1 dry bay had been torn away but the internal dry bay components were present and undamaged. The valves contained in the #1 dry bay and their positions are detailed in the chart below.

Valve Name	Valve's Final Powered Position
#1 Fuel Firewall Shutoff Valve	Closed
#1 Hydraulic Firewall Shutoff Valve	Closed
#1 Fuel Crossfeed Valve	Open
#1 Fuel Dump Valve	Closed
#2 Fuel Dump Valve	Closed
Crossfeed Primer Valve	Closed*

* The crossfeed primer valve was initially documented in the "open" position. After the valve was removed from the wing it was discovered that the "open" and "closed" position indicators on the motor housing did not match the "open" and "closed" position indicators on the valve body. Visual inspection of the valve body gate revealed that the valve was, in fact, "closed". The valve was sent to SA-ALC/LDPF for further evaluation due to the incorrect positioning of the motor housing during assembly. Examination of the valve revealed that the actuator motor housing was oriented 180 degrees from its normal position causing the "open" and "closed" indicators of the valve body

to disagree with the "open" and "closed" indicators on the motor housing. The orientation of the motor housing did not affect the operation of the valve.

DEFICIENCY: The crossfeed primer valve had an improperly installed motor housing, giving the appearance the valve was open when actually closed.

RECOMMENDATION: WR-ALC/LB direct a one-time inspection of all valves with similar construction to the crossfeed primer valve to verify proper assembly and SA-ALC/LD redesign motor housing to prevent reoccurrence and update Technical Orders.

2.2.1.3 Number Two Main Tank. The #2 fuel boost pump (P/N 60-369A, S/N 6033) was removed and visually examined. Nothing unusual was noted. It was then sent to AFRL/MLS for teardown and further analysis. In addition, samples of the charcoal-colored fuel foam from this tank were sent to AFRL/MLS for analysis. Nothing unusual was found with either the pump or the fuel foam. After removing all the foam from the #2 main tank, the #2 main tank dump pump (P/N 60-371C, S/N 4312) was also removed and visually examined. Nothing unusual was noted. The #2 main tank filter was removed and visually examined. It had filtered out some bits of fuel foam and lint, but not an unusual quantity.

2.2.1.4 Number Two Dry Bay. The #2 dry bay was intact and the internal dry bay components were present and undamaged. The valves contained in the #2 dry bay and their positions are detailed in the following chart:

Valve Name	Valve's Final Powered Position
#2 Fuel Firewall Shutoff Valve	Open
#2 Hydraulic Firewall Shutoff Valve	Open
#2 Crossfeed Valve	Open
Left Auxiliary Crossfeed Valve	Closed
Left External Crossfeed Valve	Closed
Left Bypass Valve	Closed
Left Auxiliary Fuel Dump Valve	Closed
Left External Fuel Dump Valve	Closed

2.2.1.5 Left Auxiliary Tank. The left-hand auxiliary fuel boost pump (P/N 60-371C, S/N 7572) was removed and visually examined. Nothing unusual was noted. It was then sent to AFRL/MLS for teardown and further analysis. In addition, samples of the charcoal-colored fuel foam from this tank were sent to ASC/ENF for analysis. Nothing unusual was found with either the pump or the fuel foam.

2.2.1.6 Center Dry Bay. The center dry bay was intact and the internal dry bay components were intact and undamaged. The valves contained in the center dry bay, and their positions, are detailed in the following chart:

Valve Name	Valve's Final Powered Position

Crossfeed Separation	Open
Offload Valve	Closed

2.2.1.7 Right Auxiliary Tank. The right hand auxiliary fuel boost pump (P/N 123510-01-01, S/N 373) was removed and visually examined. Nothing unusual was noted. It was then sent to AFRL/MLS for teardown and further analysis. In addition, samples of the charcoal-colored fuel foam from this tank were sent to ASC/ENF for analysis. Nothing unusual was found with either the pump or the fuel foam.

2.2.1.8 Number Three Dry Bay. The #3 dry bay was heavily damaged. The upper outer wing attachment fitting was present while the lower attachment fittings and majority of the lower wing structure of the dry bay was missing. Some of the valves were present and attached to their associated plumbing while others had been ripped from their associated plumbing but were still attached to the wing by their electrical wiring. These latter valves were positively identified by comparing the fracture faces of mating parts and by wire numbers imprinted on the electrical wires. The right external dump valve, right bypass valve, and the right external tank crossfeed valve were missing from the #3 dry bay but were recovered from the debris field attached to a portion of the fuel manifold. The valves from the #3 dry bay and their positions are detailed in the following chart:

Valve Name	**Valve's Final Powered Position**
#3 Fuel Firewall Shutoff Valve	Open
#3 Hydraulic Firewall Shutoff Valve	Open
#3 Crossfeed Valve	Open
Right Auxiliary Crossfeed Valve	Closed
Right External Crossfeed Valve	Open
Right Bypass Valve	Closed
Right Auxiliary Dump Valve	Undetermined*
Right External Dump Valve	Open

* The motor assembly had broken free from the valve body. The sliding gate valve was found in the open position but "floated" freely between the open and closed position.

2.2.1.9 Internal Tank Inspection. During and after the removal of all fuel foam, the #2 main tank and both left and right auxiliary tanks were fully inspected for the presence of foreign objects and anything else unusual (i.e., extra parts, lost tools, missing parts, excessive corrosion, improperly installed parts, etc.). None were found.

2.2.1.10 Vent System Evaluation. The vent systems for the #2 main tank and both left and right auxiliary tanks were fully examined. No evidence of blockage or foreign objects that could have caused blockage was noted. All of the vent lines appeared to be properly installed with one exception. The left hand auxiliary tank vent line just upstream of the flame arrester was properly mated to the next line, but the connecting Wiggins fitting did not appear to have been screwed together at the time of impact. This section of vent line and Wiggins fitting were removed from the wing and sent to AFRL/MLS for further examination and analysis. AFRL concluded this

Wiggins was not mechanically engaged at the time of impact, but would not have played a contributory part in the mishap.

2.2.1.11 Conclusion. The position of the fuel control valves is consistent with crossfeed operation from one or both fuselage tanks. The #1, #2, and #3 crossfeed valves and the crossfeed separation valve (#4 was not found/recovered) as well as the right external tank crossfeed valve and the right external dump valve were found open. This is the normal configuration of the fuel control valves when using fuel from one or both fuselage tanks to feed all four engines. All other recovered fuel and hydraulic control valves were in their expected/correct position for an aircraft with one engine intentionally shut down and crossfeeding from one or both fuselage tanks. For example, the #1 fuel and hydraulic firewall shutoff valves were in the closed position. Since the crew had accomplished the Engine Shutdown Procedure for the #1 engine, these valves were closed when the #1 engine Fire Emergency Control Handle (fire handle) was pulled.

2.2.2 Fuel Control Panel: The fuel panel was removed from the main cockpit wreckage area. The position of the switches upon recovery aboard ship were recorded as follows:

<u>Left Dump Valve Switch</u>	Red guard was down with switch in the NORM position.
<u>Right Dump Valve Switch</u>	The red guard was missing. The switch was in the NORM position.
<u>Boost Pump Switches</u>	The switch backs were out of all the boost pump switches. The position of the boost pump switches could not be determined due to the damage to the individual switches.
<u>Crossfeed Valve Switches</u>	The #1, #2, #3, and #4 crossfeed valve switches were CLOSED. The Left Auxiliary (Aux) crossfeed valve switch and Left Bypass valve switch were OPEN. The knob for the Left External crossfeed valve was missing, but based on the flat on the shaft of the switch it appeared that the switch was in the CLOSED position. The Crossfeed Separation valve switch was in the OPEN position. The Right External, Right Bypass, and Right Aux crossfeed valve switches were all in the CLOSED position.

These switch positions cannot be considered a reliable indication of their position at the time of power loss. Crew action after electrical power loss was likely. Additionally, the effects of impact forces and recovery efforts must be considered.

Only three of the fuel gauges were present. The #1 fuel quantity indicator was detached from the panel and hanging by the wiring harness with the faceplate and needle missing. The left Aux fuel quantity indicator was present. Although it was encrusted with corrosion it appeared to indicate ~ 4,000 pounds. The fuel pressure indicator was present and indicated ~ 12.5 psi. A more detailed analysis of the gauge by an instrument expert from the Air Force depot in Oklahoma City verified the 4,000 pound reading on the left Aux fuel quantity indicator and established that the #1 fuel quantity indicator was reading 7,000 lbs. All other fuel quantity gages were missing from the panel.

2.2.3 Auxiliary Fuel Panel: The Auxiliary Fuel panel was removed from the main cockpit wreckage area. Also, this panel contains an interphone control panel, an anti-skid test panel, the fuel governing check switches, and an oxygen regulator.

The position of the switches upon recovery aboard ship were recorded as follows:

- The interphone panel was present but damaged.
- Fuel Governing Check Switches – All four fuel governing check switches were present, with the red guard closed and safety wired.
- Anti-Skid Test Panel – The anti-skid test panel was present. All four of the test lights were missing. The test switch was in the center (spring loaded) position.
- The oxygen regulator was missing.
- The left side Tanker Ready, Fuel Flowing, and Hyd Press OFF lights were present.
- The left hose guillotine switch was present, with the red guard closed.
- The left Reel Response switch was in the NORMAL position.
- The left Reel Fuel Valve switch was missing the knob but the "flat" on the switch shaft indicated that the switch was probably in the AUTO position.
- The left pod fuel pressure gage was missing.
- The left reel control power switch was in the OFF position.
- The left HYD Press switch was in the OFF position.
- The left Reel Control switch was in the REWIND position.
- The left Emergency Trail switch was in the NORMAL position.
- The left Stowed and Locked light was present.
- The left Fuselage Tank fuel quantity gage was present and indicated ~ 500 pounds.
- The left Fuselage Tank Pump #1 switch was in the ON position.
- The left Fuselage Tank Pump #2 switch position could not be determined due to damage.
- The left Fuel SCH Reset Switch position could not be determined (toggle broken).
- The left Fuel Flow Counter was present and was set for zero fuel flow scheduled and transferred.
- The Pod Lights switch was set to BRIGHT.
- The Pod and Hose Illumination switch was set to ON.
- The fuel manifold pressure gage was missing.
- The fuselage tank empty light was present.
- The right side Tanker Ready and Fuel Flowing lights were present. The HYD Press Off light was missing.
- The right hose guillotine switch was present; the red guard was broken with the switch in the OFF position.
- The right Reel Response switch was in the NORMAL position.
- The right Reel Fuel Valve switch was missing the knob with the "flat" on the switch shaft rotated approximately 45 degrees clockwise.
- The right pod fuel pressure gage was present. The glass was broken and the gage was unreadable.
- The right reel control power switch was in the OFF position.
- The right HYD Press switch was in the ON position.

- The right Reel Control switch was in the REWIND position.
- The right Emergency Trail switch was in the NORMAL position.
- The right Stowed and Locked light was present.
- The right Fuselage Tank fuel quantity gage was present and indicated ~ 0 to 100 pounds.
- The right Fuselage Tank Pump #1 and #2 position could not be determined due to damage.
- The right Fuel SCH Reset Switch was missing.
- The right Fuel Flow Counter was present and was set for 9999 fuel flow scheduled and 0000 transferred.
- IRF Panel Lights Rheostat – The IFR panel lights rheostat was positioned to ~4 o'clock position.
- Engine Instrument and Floodlights Rheostat – The rheostat was positioned to near the full bright position.

These switch positions cannot be considered reliable due to crew actions after electrical power loss, impact forces, or recovery efforts.

2.2.4 Right Fuselage Tank and Components

2.2.4.1 Right Fuselage Tank and Mating Cradle. The right fuselage tank and mating cradle (P/Ns 8614201-1 and 8614150-1 respectively; assembly S/N 019) were recovered. Primarily, this tank was recovered for its fuel quantity gauge, but there was also interest in evaluating its two fuel pumps, fuel quantity probe, and fire suppression foam. Because a portion of the catwalk, which is installed between the two fuselage tanks on an aircraft and only pinned to the right hand tank, was still pinned to this tank in two locations, this tank was positively identified as the right hand fuselage tank. The right tank was recovered still attached to its cradle, which was still attached to the section of cargo floor immediately beneath the cradle. This section of cargo floor was slightly larger than the cradle footprint and had torn away from the surrounding cargo floor. The cradle was relatively undamaged. The forward section of the tank had been crushed from impact forces. All external fuel supply and vent lines (including the manual shutoff valve) had been stripped from the tank.

2.2.4.2 Right Fuselage Tank – External & Internal Inspection. All the fuel foam in the right fuselage tank was removed to facilitate an internal inspection. Samples of the charcoal-colored foam from this tank was removed and visually examined. In addition, these samples were sent to ASC/ENF for further examination. Nothing unusual was noted. The inside of the tank was fully inspected for the presence of foreign objects and anything else unusual (i.e., extra parts, lost tools, missing parts, excessive corrosion, improperly installed parts, etc.). The fuel supply lines, that is the lines and check valves from the pumps to the top of the tank, were found to be properly installed and unobstructed. All three check valves in this fuel supply manifold were installed properly and their flappers operated easily. The supply and return lines for the ejector pump were installed correctly. The check valve in the ejector pump pick-up line was installed correctly and its flapper operated easily. Neither the supply line, return line, nor the pick-up line for the ejector pump were obstructed. The only thing unusual noted in this tank was the presence of the gravity fill tube below the gravity fill port and the presence of the impingement cage around the refuel

valve. The presence of these items would not adversely affect tank performance, but their presence is unusual since these items should have been removed in 1990 via TCTO 1C-130-1329. Nothing else unusual was noted.

2.2.4.3 Right Fuselage Tank Refueling Panel and Fuel Gauge. The aft end of the tank, including the fuselage tank refueling control panel, was relatively undamaged. The level control valve switch was positioned to CLOSED and the panel lights switched ON. The dial face of the fuel quantity gauge (P/N B118-249, S/N M2194C), which had its glass cover intact, indicated approximately 400 lbs. A more detailed analysis of the gauge by an instrument expert from the Air Force's depot in Oklahoma City indicated a gauge reading of approximately 300 lbs.

2.2.4.4 Right Fuselage Tank Fuel Pumps. Both fuel pumps were removed from the fuselage tank after some difficulty. The front of the fuselage tank had partially crushed around the pumps which necessitated the cutting of the fuselage tank for removal. Both of the pumps (P/Ns 60-371B; S/Ns 11283 and 11305) showed minor signs of damage but this was not considered unusual given the impact damage to the front of the fuselage tank. Other than the observed impact damage, nothing unusual was noted. However, both pumps were sent to AFRL/MLS for further teardown and examination. Subject pumps were successfully dry-run for at least one minute. There was no evidence found to suggest that any of the pumps were not in operating condition at the time of power loss during the mishap sequence.

2.2.4.5 Right Fuselage Tank Fuel Probe (Identification tags no longer attached). This probe was removed from the right hand fuselage tank. It was visually examined and no defects, such as the presence of foreign objects, were noted that might have shorted the "conductors" together resulting in erroneous readings. However, the middle of the probe was damaged from impact -- one 45° bend was present near the middle of the probe. The probe was examined further at AFRL/MLS with no defects noted that would affect its functionality.

2.2.5 Left Fuselage Tank and Components

2.2.5.1 Left Fuselage Tank and Mating Cradle. Based upon rationale presented in the C-130 Broad Area Review report, the left fuselage tank and mating cradle (P/Ns 8614201-1 and 8614150-1 respectively; Assembly S/N 017) were recovered. This tank was recovered for its fuel quantity gauge, its two fuel pumps, fuel quantity probe, associated wiring, and fire suppression foam. The left tank was recovered still attached to its cradle, which was still attached to the section of cargo floor immediately beneath the cradle. This section of cargo floor was slightly larger than the cradle footprint and had torn away from the surrounding cargo floor. The cradle was relatively undamaged. The forward section of the tank had been crushed from impact forces. All external fuel supply and vent lines (including the manual shutoff valve) had been stripped from the tank.

2.2.5.2 Left Fuselage Tank – External & Internal Inspection. All the fuel foam in the left fuselage tank was removed to facilitate an internal inspection. Samples of the charcoal-colored fuel foam from this tank were removed and visually examined. In addition, these samples were sent to ASC/ENF for further examination. Nothing unusual was noted. The inside of the tank

was fully inspected for the presence of foreign objects and anything else unusual (i.e., extra parts, lost tools, missing parts, excessive corrosion, improperly installed parts, etc.). The fuel supply lines, that is the lines and check valves from the pumps to the top of the tank, were found to be properly installed and unobstructed. All three check valves in this fuel supply manifold were installed properly and their flappers operated easily. The supply line to the ejector pump was installed correctly except for one loose (i.e., finger tight) B-nut. The return line from the ejector pump was installed correctly. The check valve in the ejector pump pick-up line was installed correctly and its flapper operated easily. Neither the supply line, the return line, nor the pick-up line for the ejector pump were obstructed. However, two unattached metal plates (P/Ns 8614271-14) were found near the inlet for the ejector pump pick-up line. The tank's fuel foam trapped the plates against the tank wall where they were rendered harmless. Nothing else unusual was noted.

2.2.5.3 Left Fuselage Tank Refueling Panel and Fuel Gauge. The aft end of the tank, including the fuselage tank refueling control panel, was relatively undamaged. The level control valve switch was positioned to CLOSED and the panel lights switched OFF. The dial face of the fuel quantity gauge (P/N B118-249, S/N M2185C), which had its glass cover broken, indicated between 500 and 600 pounds. A more detailed analysis of the gauge by an instrument expert from the Air Force's depot in Oklahoma City indicated a gauge reading slightly less than 600 pounds.

2.2.5.4 Left Fuselage Tank Fuel Pumps. Both fuel pumps (P/N 60-371B, S/Ns 11279 and 11284) were removed from the fuselage tank after some difficulty. The front of the fuselage tank had partially crushed around the pumps. Nothing unusual was noted, however, both pumps were sent to AFRL/MLS for further teardown and examination. Subject pumps were successfully dry-run for at least one minute. There was no evidence found to suggest that any of the pumps were not in operating condition at the time of power loss during the mishap sequence.

2.2.5.5 Left Fuselage Tank Fuel Probe (P/N EA805-3201). This probe was removed from the left-hand fuselage tank. It was visually examined and no defects, such as the presence of foreign objects, were noted that may have shorted the probe's "conductors" together resulting in erroneous indications. However, the top of the probe was damaged from impact -- two 90° bends were present near the top of the probe. The probe was examined further by the AFRL/MLS with no defects noted that would affect its functionality.

DEFICIENCY: Several nonstandard practices were identified with the King 56 fuselage tanks. First, extraneous hardware was left in both fuselage tanks following an apparent improperly accomplished Time Change Technical Order (TCTO). Next, fleet-wide evidence suggests fuselage tanks are not being regularly drained of water, potentially leading to tank corrosion. The discovery of a coating of Corrosion Preventative Compound (CPC) in one tank is evidence of a nonstandard procedure resulting from unanticipated corrosion.

RECOMMENDATION: WR-ALC/LB direct a one-time inspection of all fuselage tanks to ensure proper completion of TCTOs and check for corrosion and presence of foreign objects.

2.2.6 Engine Instrument Panel: The engine instrument panel was recovered with all gauges in place or attached with the exception of the following: #2 and #4 tachometers, #1 fuel flow, #1 oil temperature, #4 oil pressure, and the #1 oil cooler flap position indicator. The gauges on the engine instrument panel receive power from a number of different sources and therefore react differently to a loss of power. Also, depending on the design of the gauges, they react differently to the impact forces. The engine instrument panel was sent to OC-ALC for analysis.

2.2.6.1 Torquemeters: The torquemeters are powered from the AC and Engine Instrument bus (which receives power from the Essential AC bus) and retain their reading when electrical power is lost. The #1 torquemeter indicated 25,800 to 25,900 in-lbs of torque. The #1 engine had been shutdown prior to the loss of electrical power. With power applied to a torquemeter on an engine that is not operating, the torquemeter will rotate due to loss of signal from the torquemeter pickups. The #2 and #4 torquemeters were indicating negative torque within the allowable limits of the Negative Torque System (NTS). The #3 torquemeter was indicating a negative torque of 2800 in-lbs which is outside the maximum negative torque limit of negative 1860 in-lbs.

2.2.6.2 Tachometers: The tachometer is powered from a gearbox mounted tachometer generator and operates independently of the aircraft's electrical system. The tachometers would therefore have continued to operate after the last engine failed and electrical power was lost. The #1 tachometer indicated zero (the #1 engine was shut down by the crew). The #3 tachometer indicated 29% which correlates to a propeller windmilling on NTS. The #2 and #4 indicators were not recovered.

2.2.6.3 Turbine Inlet Temperature (TIT) Indicators: The TIT indicators are powered by the AC Instrument and Engine Fuel Control bus and retain their readings when electrical power is lost. The TIT of an operating engine ranges from approximately 550°C, for an engine at idle, to a maximum TIT of 1083°C for an engine at maximum power. The recovered TIT indicators all reflected temperatures of less than 550°C.

The #1 engine TIT indicated 240-250°C. This correctly equates to the expected TIT of an engine that has been recently feathered. When a propeller is feathered the engine and propeller rotation stops within 10 seconds. Since the engine is not rotating, cooling air is not flowing through the engine and the TIT slowly decreases as the turbine cools.

The #2 engine TIT indicated just over 70°C. The #2 engine had not been feathered and was rotating. Since the engine was still rotating, the TIT decreased rapidly due to the cooling air passing through the engine.

The #3 engine TIT indicated 400-410°C. The #3 engine was the last engine to flameout. After it flamed out, the TIT would have decreased until its engine generator dropped off line at approximately 92%. At that time, the indicator would have retained the reading at the time of the electrical power loss.

The #4 engine TIT indicated just over 300°C. The #4 engine failed just prior to the #3 engine so this engine had slightly more time to cool before the last engine flamed out and prior to power being lost to the TIT indicator.

2.2.6.4 Fuel Flow Indicators: The fuel flow indicators are powered by the AC Instrument and Engine Fuel Control bus and retain their reading when electrical power is lost. However, due to the design of the indicators, they are easily changed by impact forces. No usable information could be obtained from the fuel flow indicators.

2.2.6.5 Oil Temperature, Oil Quantity, and Oil Cooler Flap Position Indicators: The Essential DC bus powers all three of these indicators. DC powered indicators go "off scale" when electrical power is lost. All indications obtained from these instruments reflected this "off scale" condition indicating that Essential DC power was unavailable at the time of impact.

2.2.6.6 Oil Pressure: The oil pressure indicators receive power from the AC Instrument and Engine Fuel Control bus. The power for the #3 and #4 oil pressure indicators are reduced to 26 VAC through the #1 step down transformer while the #1 and #2 oil pressures are supplied by the #2 step down transformer. The design of these indicators is such that the indications are easily changed as a result of impact forces. No usable information could be obtained from the oil pressure indicators.

2.2.7 Engines and Engine Components. This evaluation is an assessment of the condition of the #1, #2, and #3 engines as found after recovery from the ocean floor. The recovered engines were shipped to SA-ALC for teardown and inspection.

2.2.7.1 #1 Engine. This engine was severely damaged. The propeller was not attached to the engine. The Reduction Gearbox (RGB) and Accessory Drive Housing Assembly (ADHA) appeared to have dissolved due to the effect of the salt water on the magnesium casings. Attaching components to the RGB and ADHA were laying in the Quick Engine Change (QEC) kit restrained by their connecting hardware (hoses, ducts, and wiring). All cowlings were missing and the left upper longeron was detached at its aft point. Several components were detached from their mounts but were attached by their connecting hardware (hoses, plumbing, ducting, wiring). The power section was relatively intact. However, the exhaust nozzle was crushed on the right side, the inlet had a considerable amount of corrosion-related foreign debris present along with mud from the ocean floor, and most of the external engine components exhibited extensive corrosion.

The serial numbers for the major components are as follows:

Engine	AD00109962	
Compressor Module	AD0C509962	
Turbine Module	AD0T509962	
Gearbox Assembly	00AG022547	(not recovered, per engine records only)
Torquemeter Assy.	n/a	(not recovered, not recorded in engine records)

Fuel Control	189366	(P/N 440970-2, Model #AP-B3)
Fuel Pump	PE5170T	(P/N 022489-054-03)
TD Valve	n/a	(not legible due to extensive corrosion)
TD Amplifier	T-9912	(Bendix Model No. ET-B4, P/N 179684-1)

The turbine module was removed as a unit. Aside from some surface corrosion, the result of exposure to salt water, the first stage vanes were in remarkably good condition, showing no signs of burning and no obvious cracks. The fourth stage blades were also in good condition, with no broken or bent blades present.

The thermocouples were also in very good condition – they also showed no signs of burning or erosion. There were some deposits of mud (or some other foreign debris) on the probe tips.

Large clumps of mud were present in the combustion chambers, and both the combustion cans and the fuel nozzles exhibited signs of extensive corrosion.

There was a moderate amount of mud and other foreign matter present in the compressor inlet, as well as signs of corrosion damage. There were a few (3) first stage compressor blades bent in the direction of rotation, but since they were not in close physical proximity to each other, these bent blades are most likely the result of impacts with foreign debris ingested by the engine sometime during the crash. There were no signs of rotation damage in either the compressor inlet or the compressor bleed valve ports.

The Fuel Control, Fuel Pump, and TD Valve were removed for detailed evaluation (see below). No significant amount of fuel residue was found in the fuel lines.

FUEL CONTROL TEARDOWN & INSPECTION: A preliminary inspection of the "cutoff valve" lever tension indicated that the Fuel Control was in the Closed position. This was confirmed when fuel shutoff valve motor (a.k.a. the "Geneva lock") was removed. Scribe marks on the shaft indicated it was in the Closed position, and the fuel supply had been cut off. This is consistent with the fire handle having been pulled.

Extensive corrosion was seen inside the fuel control body. Some contamination was also found in the fuel control body, which appeared to be amorphous Aluminum Hydroxide, a by-product of corrosion when aluminum parts are exposed to salt water, and previously found in the #4 engine fuel control. No abnormal wear was indicated on any internal parts. All internal moving parts appeared to still be functioning properly and able to move freely.

FUEL PUMP TEARDOWN & INSPECTION: Extensive corrosion was seen on the outside of the fuel pump body and filter assembly. No obvious damage or abnormalities were noted on any internal parts. All parts showed normal wear and appeared to have been operative at the time of the mishap.

TD VALVE TEARDOWN & INSPECTION: Numerous safety seals were missing due to corrosion. The metering valve train appeared to be functioning correctly. Fuel Accessory shop

technicians verified the proper alignment of the metering valve drive gears from previous overhaul marks on these gears. The gears indicated that the TD Valve was in a "put" condition at the time electrical power was lost. The remainder of the TD Valve was disassembled and inspected for abnormalities. None were noted.

TD AMPLIFIER INSPECTION: One loose TD Amplifier was recovered. Since the other three engines had TD Amps attached, investigators determined it was the #1 TD Amp.

The TD Amp appeared to have been damaged by an impact with another object, allowing salt water to enter the housing. The physical damage and resulting corrosion of the circuit boards rendered the unit inoperable. As a result, no bench tests could be performed on the unit.

CONCLUSION: Inspection of the Fuel Control confirmed that the #1 engine had been shut down by the crew prior to impact. If the engine had been windmilling, it was not rotating fast enough or did not hit the water with enough force to cause rotational damage to the engine. The fact that the TD Valve was shown to have been in a "put" condition indicated the TD system was trying to feed more fuel to the engine. Based on the physical examination of this engine, there was no mechanical failure or physical damage that would have caused this engine to cease operation.

2.2.7.2 #2 Engine. This engine was severely damaged. The propeller was not attached to the engine. The RGB and ADHA appeared to have dissolved due to the effect of the salt water on the magnesium casings. Attaching components to the RGB and ADHA were laying in the QEC restrained by their connecting hardware (hose, duct, and wiring). All cowlings were missing and the left upper longeron was detached at its aft point. Several components were detached from their mounts but were attached by their connecting hardware (hoses, plumbing, ducting, wiring). The power section was relatively intact. However, the exhaust nozzle was crushed on the bottom side, the inlet had a considerable amount of corrosion-related foreign debris present along with mud from the ocean floor, and most of the external engine components exhibited extensive corrosion. [NOTE: When the engine was being prepared for shipment to SA-ALC for teardown and inspection, portions of the QEC that were hanging from the engine were removed and put in storage at Travis AFB, CA, including the TD Amp.]

The serial numbers for the major components are as follows:

Engine	AD00107677	
Compressor Module	AD0C507677	
Turbine Module	AD0T50N007	
Gearbox Assembly	00AG023282	(not recovered, per engine records only)
Torquemeter Assy.	n/a	(not recovered, not recorded in engine records)
Fuel Control	BR340124	(P/N 440970-2, Model #AP-B3)
Fuel Pump	n/a	(data plate missing)
TD Valve	n/a	(not legible due to extensive corrosion)
TD Amplifier	n/a	(recovered with the engine, but left in storage at Travis AFB. See below for details.)

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The turbine module was removed as a unit. Aside from some surface corrosion, the result of exposure to salt water, the first stage vanes were in remarkably good condition, showing no signs of burning and no obvious cracks. The fourth stage blades were also in good condition, with no broken or bent blades present.

The thermocouples were also in very good condition – they also showed no signs of burning or erosion. There were some deposits of mud (or some other foreign debris) on the probe tips.

A considerable amount of mud was present in the combustion chambers, and both the combustion cans and the fuel nozzles exhibited signs of extensive corrosion.

There was a large amount of mud and other foreign matter present in the compressor inlet, as well as signs of corrosion. There were no signs of rotation damage in either the compressor inlet or the compressor bleed valve ports.

The Fuel Control, Fuel Pump, and TD Valve were removed for detailed evaluation (see below). When the fuel flowmeter was drained, the contents consisted almost entirely of fuel. Other fuel system components contained somewhat more water, but something less than 10% (by volume).

FUEL CONTROL TEARDOWN & INSPECTION: A preliminary inspection of the "cutoff valve" lever tension indicated that the Fuel Control was in the Open position. This was confirmed when fuel shutoff valve motor (a.k.a. the "Geneva lock") was removed. Scribe marks on the shaft indicated it was in the Open position.

Moderate corrosion was seen inside the fuel control body. Some contamination was also found in the fuel control body, which appeared to be more amorphous aluminum hydroxide. No abnormal wear was indicated on any internal parts. All internal moving parts appeared to still be functioning properly and able to move freely.

According to the engine maintenance records, the fuel control was replaced on 2 Nov 96.

FUEL PUMP TEARDOWN & INSPECTION: Extensive corrosion was seen on the outside of the fuel pump body and filter assembly. No obvious damage or abnormalities were noted on any internal parts. All parts showed normal wear and appeared to have been operative at the time of the mishap.

TD VALVE TEARDOWN & INSPECTION: Numerous safety seals were missing due to corrosion. The data plate was also severely corroded and illegible. The metering valve train appeared to be functioning correctly. Fuel Accessory shop technicians verified the proper alignment of the metering valve drive gears from previous overhaul marks on these gears. The gears indicated that the TD Valve was in a "put" condition at the time electrical power was lost. The remainder of the TD Valve was disassembled and inspected for abnormalities. None were noted.

TD AMPLIFIER INSPECTION: A TD Amp was recovered with this engine, hanging by its wiring harness. When the engine was being prepared for shipment to SA-ALC for teardown and inspection, portions of the QEC that were hanging from the engine were removed and put in storage at Travis AFB, CA, including the TD Amp. Investigators at Travis AFB inspected the unit and determined it was sufficiently damaged (from the impact and by corrosion) so as not to have been operable. This damage meant that no bench tests could be performed on the unit, and so it didn't need to be shipped.

CONCLUSION: Inspection of the Fuel Control confirmed that the #2 engine had not been intentionally shut down by the crew prior to impact. If the engine had been rotating, it was not rotating fast enough or did not hit the water with enough force to cause rotational damage to the engine. The fact that the TD Valve was shown to have been in a "put" condition indicated the TD system was trying to feed more fuel to the engine. Based on the physical examination of this engine, there was no mechanical failure or physical damage that would have caused this engine to cease operation.

2.2.7.3 #3 Engine. This engine was basically intact. The propeller was not attached to the engine. The RGB and the ADHA appeared to have dissolved due to the effect of the salt water on the magnesium casings. Attaching components to the RGB and ADHA were laying in the QEC, restrained by their connecting hardware (hoses, plumbing, ducting, wiring). Most of the external engine components exhibited extensive corrosion.

The serial numbers for the major components are as follows:

Engine	AD00104933	
Compressor Module	AD0C504933	
Turbine Module	AD0T504933	
Gearbox Assembly	00AG025541	(not recovered, per engine records only)
Torquemeter Assy.	n/a	(data plate missing, not recorded in engine records)
Fuel Control	BR339516	(P/N 440970-2, Model #AP-B3)
Fuel Pump	PE10379	(P/N 022489-054-03)
TD Valve	n/a	(not legible due to extensive corrosion)
TD Amplifier	n/a	

The turbine module was removed as a unit. Aside from some surface corrosion, the result of exposure to salt water, the first stage vanes were in remarkably good condition, showing no signs of burning and no obvious cracks. Some foreign debris (appeared to be mud from the ocean floor) was found on the first stage vanes. The fourth stage blades were also in good condition, with no broken or bent blades present.

The thermocouples were also in very good condition – they also showed no signs of burning or erosion. There were some deposits of mud (or some other foreign debris) on the probe tips.

Both the combustion cans and the fuel nozzles exhibited signs of corrosion, but very little foreign matter was present in the combustion chambers.

There was a considerable amount of mud and other foreign matter present and extreme corrosion damage in the compressor inlet. There were no signs of rotation damage in either the compressor inlet or the compressor bleed valve ports.

The Fuel Control, Fuel Pump, and TD Valve were removed for detailed evaluation (see below). When the fuel flowmeter was drained, the contents consisted of almost entirely fuel. Other fuel system components contained somewhat more water, but something less than 10% (by volume).

FUEL CONTROL TEARDOWN & INSPECTION: A preliminary inspection of the "cutoff valve" lever tension indicated that the Fuel Control was in the Open position. This was confirmed when fuel shutoff valve motor (a.k.a. the "Geneva lock") was removed. Scribe marks on the shaft indicated it was in the Open position.

Very little corrosion was seen inside the fuel control body. Almost no contamination was found in the fuel control body. No abnormal wear was indicated on any internal parts. All internal moving parts appeared to still be functioning properly and able to move freely.

FUEL PUMP TEARDOWN & INSPECTION: Extensive corrosion was seen on the outside of the fuel pump body and filter assembly. No obvious damage or abnormalities were noted on any internal parts. All parts showed normal wear and appeared to have been operative at the time of the mishap.

TD VALVE TEARDOWN & INSPECTION: Numerous safety seals were missing due to corrosion. The metering valve train appeared to be functioning correctly. Fuel Accessory shop technicians verified the proper alignment of the metering valve drive gears from previous overhaul marks on these gears. The gears indicated that the TD Valve was in a "put" condition at the time electrical power was lost. The remainder of the TD Valve was disassembled and inspected for abnormalities. None were noted.

TD AMPLIFIER INSPECTION: The TD Amp housing appeared to have been crushed by the tremendous pressure of the water as the wreckage sank (it would have exceeded 2200 psi), allowing salt water to enter the housing. The physical damage and resulting corrosion of the circuit boards rendered the unit inoperable. As a result, no bench tests could be performed on the unit.

CONCLUSION: Inspection of the Fuel Control confirmed that the #3 engine had not been intentionally shut down by the crew prior to impact. The engine did not hit the water with enough force to cause rotational damage, as evidenced by the fact that the nacelle was still intact. The fact that the TD Valve was shown to have been in a "put" condition indicated the TD system was trying to feed more fuel to the engine. Based on the physical examination of this engine, there was no mechanical failure or physical damage that would have caused this engine to cease operation.

2.2.7.4 #4 Engine. The #4 Engine was recovered during the initial salvage operation in early 1997. A teardown and inspection of the engine was performed in February 1997 during the original mishap investigation. A follow-up detailed inspection of the Temperature Datum (TD) Amplifier, TD Valve, Fuel Control, and Fuel Pump was performed in early 1998.

This engine was basically intact. The recovered engine had no torquemeter attached, but the starter and a small piece of the RGB remained (attached to the right-hand side tie strut). The remaining piece of the RGB showed definite signs of corrosion as a result of exposure to sea water. Most of the engine cowling and QEC components (tubing, wiring, air-oil cooler, etc.) were still attached, but extensively damaged. The oil pump and oil filter (mounted on the front side of the ADHA) were missing, the speed sensitive valve and speed sensitive control (also mounted on the front side of the ADHA) were both damaged, and most of the ADHA had dissolved as a result of exposure to sea water. The tailpipe was missing, and the aft edge of the exhaust cone was dented and pushed inward. As far as could be determined, all other engine-mounted accessories were still attached. Most of the external engine components exhibited a moderate amount of corrosion.

The serial numbers for the major components are as follows:

Engine	AD00106876	
Compressor Module	AD0C506876	
Turbine Module	AD0T503969	
Gearbox Assembly	00AG025824	(per engine records only)
Torquemeter Assy	n/a	(not recorded in the engine records)
Fuel Control	BR339480	(P/N440970-2, Model AP-B3)
Fuel Pump	PE 533-S	(Pesco P/N 022489-054-03)
TD Valve	10770	(P/N 33033-4, Model PB-A3)
TD Amplifier	3550	(Raven type, P/N 23052609A)

A 10" x 16" window was cut into the turbine casing using a fire rescue cutting saw (a.k.a. a "K-12" saw) for inspection of the turbine stators and blades. A couple of small cracks in the leading edges of a couple of second stage stators were found, but this is normal for any operating engine. No impact damage or signs of rubbing or scraping was observed on the case, the stators, the blades, or the rotor. No abnormalities were detected.

One thermocouple was removed for inspection. It showed carbon deposits and erosion consistent with normal use and wear. The remaining thermocouples were not removed because a more complete inspection of the turbine was possible (using the technique described above).

The lower half of the compressor case was removed to allow for inspection. No impact damage or signs of rubbing or scraping were observed on the case, the stators, the blades, or the rotor. No signs of compressor shift were noted. No abnormalities were detected.

Three fuel nozzles were removed and disassembled for inspection. The face of each nozzle exhibited signs of corrosion. When blown through, no obstruction was noted, and a small amount

of fuel residue was found. The nozzle tips were removed to expose the internal filter screens. The filter screens in the fuel nozzles were visually clear of debris, exhibiting only a minor amount of corrosion.

Liquid samples were taken from the scavenge oil filter, the low pressure fuel filter, the high pressure fuel filter, the filter in the fuel heater strainer, and from the main fuel control. A sample of the white substance from the fuel control was also taken. These samples were submitted for chemical analysis. The results were consistent with the wreckage having been submerged in seawater, and revealed nothing else unusual.

The Fuel Control, Fuel Pump, and TD Valve were removed for detailed evaluation (see below). The fuel system had been breached as a result of damage incurred at impact, allowing seawater to enter. When opened, the low pressure fuel filter, the high pressure fuel filter, and the filter in the fuel heater strainer all contained some sea water mixed with residual fuel. No fuel residue was found when the fuel flowmeter was removed or when the fuel manifold lines were disconnected.

FUEL CONTROL TEARDOWN & INSPECTION: The fuel control was partially disassembled for inspection. The fuel shutoff valve was found in the Open position. Some contamination was found inside the fuel control body. It was a white, pasty substance, similar in consistency to a mixture of flour and water. A chemical analysis performed at Allied Signal on a similar substance taken from the TD Valve identified it to be amorphous Aluminum Hydroxide.

As part of a follow-up detailed inspection of the Fuel Control, the fuel control was partially disassembled for examination a second time at the Pneudraulics Systems Repair Section at Kelly AFB in January 1998. Only enough components were removed to allow for removal and inspection of the metering valves. The drive end was disassembled for inspection of the internal components, but no internal parts were removed.

The amorphous Aluminum Hydroxide seen during our initial internal inspection of the fuel control was no longer clearly evident. However, considerable corrosion had built-up on the non-stainless steel components. When the metering valves were finally removed, very little foreign matter was visible. There were strong indications the debris that was present was the result of cross-contamination from corrosion that developed elsewhere inside the fuel control, and there was no evidence to indicate the debris was present at the time of the mishap. A small drop of what was suspected to be more amorphous Aluminum Hydroxide was seen on one part of the metering valve (its composition was not known at that time).

The main fuel control was subsequently brought to the Aerospace Equipment Systems Division of Allied Signal (Bendix) in South Bend, Indiana. Engineers at Allied Signal started by examining the components that had already been removed, then continued the disassembly started at Kelly AFB. Numerous components were covered by corrosion making disassembly difficult. Aside from the corrosion described above, no abnormalities were noted anywhere in the fuel control.

FUEL PUMP TEARDOWN & INSPECTION: No inspection of the fuel pump was performed during the original mishap investigation in February 1997. A follow-up detailed inspection of the

Main Fuel Pump was performed at the Pneudraulics Systems Repair Section at Kelly AFB in January 1998. The teardown was also witnessed by a technical representative from Sundstrand Aerospace, Rockford, IL.

Technicians removed the filter assembly, impeller housing, gear housing, front cover, pump gears, and gear shaft bearings, leaving a bare pump housing. Inspection of the housing revealed no signs of cavitation damage, but there was pitting in the pump gear bores. Due to the location and nature of the pitting, it was concluded the pitting was the result of corrosion. Inspection of the bearings revealed no abnormal wear. There were small indications of cavitation in the "bridge" area, but this is considered normal. In summary, we found no evidence to indicate that cavitation had occurred in the #4 main fuel pump.

TD VALVE TEARDOWN & INSPECTION: No inspection of the TD Valve was performed during the original mishap investigation in February 1997. A follow-up detailed inspection of the TD Valve was performed at the Pneudraulics Systems Repair Section at Kelly AFB in January 1998. A visual inspection noted that the start schedule adjustment indicator was pushed almost all the way to the lean limit. The safety wire for this adjustment had been removed and no remnants were present.

The TD valve was then tested on a TD valve flow-bench in an attempt to determine whether the valve was in a "put", "take", or "null" condition. However, no fluid flow was observed from either the output or bypass ports, even when subjected to 300 psi supply pressure. No disassembly was performed in order not to disturb the position of the metering valve.

The TD valve was subsequently brought to the Aerospace Equipment Systems Division of Allied Signal (Bendix) in South Bend, Indiana, for detailed examination. Engineers at Allied Signal attempted to bench test of the TD Valve as well, but were likewise unsuccessful. Unable to perform a bench test, disassembly of the TD Valve was required to determine whether it was in a "put", "take", or "null" condition. The side cover plate was removed and the original alignment marks were still visible on the internal drive gears. They indicated the TD valve was slightly in the Take regime.

Numerous internal components showed extensive signs of corrosion, including the pressurizing valve. Given the configuration of the internal valves, etc., this would explain why no flow was observed during the bench test at Kelly AFB. There is no reason to believe this corrosion was present prior to the mishap. It was at this time that a sample of the white pasty substance previously seen in the fuel control was taken from the TD Valve and found to be amorphous Aluminum Hydroxide. Aluminum Hydroxide is an expected result of exposure of aluminum components to salt water. Aside from the corrosion described above, no abnormalities were noted anywhere in the TD valve.

TD AMPLIFIER INSPECTION: No inspection of the TD Amp was performed during the original mishap investigation in February 1997. A follow-up detailed inspection of the TD Amp was performed by engineers at Kelly AFB in January 1998. The cover plate was collapsed inward from flange to flange, and it was uniformly deformed, leaving a clear impression of internal

components (including an internal partition inside the amplifier housing). The bottom side of the housing had a large, irregularly shaped hole broken into it, with a uniform deformation in the area surrounding the rupture. When the bottom of the housing ruptured, the wiring and circuit boards inside the housing were extensively damaged. The damage rendered the unit inoperable and incapable of being bench tested.

CONCLUSION: Inspection of the Fuel Control confirmed that the #4 engine had not been intentionally shut down by the crew prior to impact. The engine did not hit the water with enough force to cause rotational damage, as evidenced by the fact that most of the nacelle was still intact. The fact that the TD Valve was shown to have been in a slight "take" condition indicated the TD system was trying take fuel away from the engine. Based on the physical examination of this engine, there was no mechanical failure or physical damage that would have caused this engine to cease operation.

2.3 Aircraft Records Review

The available aircraft records, to include engine and propeller records, 781As, 781Ks, 781Hs, CAMS Maintenance History, the aircraft's TCTO history, Analytical Condition Inspection Reports, and the aircraft's Significant Historical Data Equipment History were reviewed for trends and for anything unusual. Since this mishap was thought to be related to fuel starvation, special attention was given to fuel-related write-ups. Appendix F lists the significant fuel-related write-ups for King 56 from 1 Jan 96 to 20 Nov 96. Write-ups for King 56 occurring on 21 and 22 Nov 96 were still in the aircraft's Forms Binder and this binder was lost with the aircraft. This binder was not recovered during subsequent salvage operations.

Several significant discrepancies were noted. Specifically two fuel tanks, the right hand auxiliary tank and the left hand external tank, were not fully operational due to deferred maintenance. The right hand auxiliary tank had a leak around the sump drain and the left hand external tank had a fuel quantity indicator that did not work properly. Because of lateral weight restrictions, if fuel was not placed in the left hand external tank, there must also be no fuel placed in the right hand external tank. Lastly, despite words to the contrary in the 15 Jan 98 C-130 BAR report, maintenance records indicate that the left hand fuselage tank was operational for the mishap sortie. Of other interest is the fact that there are several repeat write-ups.

Lastly, it is interesting to note that both left and right fuselage tank fuel quantity systems were written-up on 17 Nov 96. Recalibration was then performed on 20 Nov 96. Based upon this recalibration, the gauges should have been reading accurately. Because this write-up was corrected two days prior to the mishap, because fuel starvation was thought to be related to the King 56 mishap, and because one of the BAR's four "likely" scenarios involves a tank running empty, further investigation into the corrective actions was performed. Interviews with the maintenance personnel who calibrated the indicators confirmed that the indicators functioned properly after calibration.

2.3.1 Initial Fuel Load and Distribution. There are several extant records that document fuel information. The AFTO Form 151A indicates that King 56's first sortie on 22 Nov 96 landed

with 12,000 lbs. of fuel. The aircraft was then refueled. Fuel truck records indicate an onload of 4088 gallons for the second sortie, which is approximately 27,800 lbs. This data is consistent with an initial fuel load of 40,000 lbs. on the mishap sortie. However, the Form F (AFTO Form 365-4) indicates a fuel load of 39,000 lbs. The fuel load is normally documented in the aircraft records, AFTO Form 781H, which were lost with the aircraft. The AFTO Form 781H is normally the principal place to record total fuel load. The Form F is the aircraft weight and balance form completed before each flight and it normally records the total fuel and its distribution. The Form F indicates that fuel was in the main, auxiliary and external tanks.

Computerized maintenance records indicate that the right-hand auxiliary tank had a leak, and that the left external tank had an indicator problem. While unusual, it is permissible to fly with this combination of inoperative gauges in accordance with regulations if certain procedures are followed. These restrictions would include not fueling the leaking tank, and in the case of the external tanks, lateral weight limitations require that the external tanks weigh the same amount. In this case, aircrews must verify the tanks full or empty. This would force the crew to either fuel them completely full, or not fuel them at all. These are the only two ways to be completely certain that the tanks weigh the same.

The Form F and maintenance data conflict. The Form F indicates fuel in the external tanks, but not enough fuel to fill the tanks. The Form F also indicates no fuel in either fuselage tank.

Two possibilities exist: the Form F was either in error or correct. The BAR explored the first possibility. There was no indication that the external tank entry was an error because the center of gravity calculations match those for external tanks shown on the Form F. Alternatively, the loadmaster could have anticipated one fuel load, but discovered another different fuel load had actually been put on the aircraft. Because fuel alone cannot push the center of gravity location beyond its forward or aft limits, the variation in this case was only one and a half percent, there would have been little incentive to correct the error. Had the Form F been wrong, failure to correct the error would have had no safety implications. Finally, there exists the possibility that the fuel was put in the external tanks, either by error, or because the maintenance records were in error and the external tanks were in fact operational. While we cannot conclusively rule out either possibility, interviews with other engineers, loadmasters, and maintenance personnel caused the BAR to believe strongly that the fuel was put into the right hand fuselage tank and not the external tanks.

Based on the Form F, fuel servicing documentation, and an interview with the aircraft's crew chief, the BAR believes the mishap aircraft was serviced to approximately the following fuel load:

#1 Main	#2 Main	LH Aux	RH Aux	#3 Main	#4 Main
7000	7000	4000	0	7000	7000

LH External		RH External
0		0

LH Fuselage	RH Fuselage
0	8000

Table 2-1 - King 56 Probable Fuel Distribution

The BAR believes the left hand external tank was not used because the fuel quantity indicator drove off scale, low end, when its forward boost pump was turned on. Fuel was not placed in the right hand external tank in order to maintain lateral balance. The right hand auxiliary tank was not used because it leaked around the cavity drain. And finally, although the left hand fuselage tank was operational according to the aircraft records, the BAR believes it also was not used for three reasons. First, the positions of the crossfeed valves indicate the crew was fueling from one or both fuselage tanks and not the external or auxiliary tanks. Second, the crew chief indicated that the right hand fuselage tank was used, not the left. Finally, the right hand fuselage tank could readily receive all 8000 lbs. without placing any in the left hand fuselage tank.

2.3.2 Fuel Burn. Regardless of the source of the fuel on King 56, calculations show that the total amount of fuel required to fly the mishap profile is approximately 8400 lbs. These calculations were performed using T.O. 1-C-130H-1-1, and the specific amount of fuel required for each phase of the flight for the mishap sortie is shown in Table 2-2 below:

	Time (minutes)	Burn Rate (1,000 lbs/hr)	Fuel Used (1,000 lbs)	Fuel Remaining
Initial Service				40.00
Start, Taxi	15	3.00	0.75	39.25
Takeoff	2	Tables	0.30	38.95
Climb	20	Tables	2.35	36.60
Cruise	64	4.68	5.00	31.60

Table 2-2 Calculated Fuel Requirements for King 56

The validity and accuracy of these calculations was investigated further in a C-130 simulator where all the specifics for the mishap sortie (i.e., aircraft gross weight, aircraft drag, weather conditions, etc.) were input into the simulator. The simulator flight crew was then tasked to fly the mishap sortie profile. This included starting engines, taxi to the runway, taking off, climbing, leveling off and cruising, and performing all required checklists. Based upon DFDR data from King 56, the total time to perform engine start, taxi and takeoff in the simulator was nearly identical to that at Portland. Simulator time-to-climb was slightly faster than that on the DFDR--18:10 and 18:00 minutes in the simulator versus 20:00 minutes for King 56. Cruise performance (i.e., indicated airspeed and engine torques) was eventually "matched" with appropriate positioning of the throttles.

Fuel requirements from the simulator were very similar to those shown in Table 2-2. Fuel required for start, taxi and takeoff in the simulator was nearly 800 lbs. versus 1050 lbs. calculated. Fuel required for climb in the simulator was nearly 2100 lbs. versus 2350 calculated. Fuel flow

readings taken during the cruise phase in the simulator averaged at 4700 lbs/hr for all engines versus 4680 lbs/hr calculated.

The 250 lbs. differences between simulator results and calculations for both the start, taxi, takeoff and climb phases are not considered significant given the certainty of the data used (i.e., aircraft gross weight, aircraft drag, weather conditions, engine performance, etc.) and the fidelity and layout of the performance charts themselves. In short, the simulator verified, within a reasonable tolerance, that the calculated amount of fuel required to fly the mishap profile presented in Table 2-2 is correct.

C-130 Broad Area Review Report Addendum - King 56 Salvage

Section 3.0

Reevaluation of Scenarios

3.1 Scenario Analysis: After careful examination of all physical evidence, test results, and analysis, the BAR determined that King 56 engines stopped due to fuel starvation as a result of improper fuel management procedures. Of the original 20 scenarios, the description of Scenario Number 2, Variation B best describes what happened to King 56. All the other scenarios, with the exception of one, which was determined to be "Highly Improbable," have been "Refuted." Each scenario is individually addressed below. The scenarios are listed numerically in the same order as originally presented in the 15 Jan 98 C-130 BAR report.

3.1.1 Scenario Number 1. Left Hand Auxiliary Fuel Tank Run Empty

Scenario Details: With the preceding fuel load in Table 2-1, it is presumed that the engines fed from their respective main tanks for approximately the first 33 minutes of flight. For roughly the next 51 minutes, it is postulated that the engines were fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. If the switch to the right hand fuselage tank was not made, the fuel panel warning/caution lights not seen or believed, and the main tank pumps "OFF," the left hand auxiliary fuel tank would have been run empty. This may have allowed ambient air to enter the fuel supply manifold and work its way out to all four engines. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario.

	Time (min)	Fuel Used (k lbs)	Fuel Source, Duration and Quantity Used
Start, Taxi	15	0.75	Tank-to-Engine, 15 min, 750 lbs
Takeoff	2	0.30	Tank-to-Engine, 2 min 300 lbs
Climb	20	2.35	Tank-to-Engine, 20 min, 2350 lbs
Cruise	64	5.00	Tank-to-Engine, 13 min, 1000 lbs. then Left Hand Auxiliary, 51 min, 4000 lbs

Table 3-1: Fuel Burn Profile for Scenario Number 1

Conclusion: Two new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section and one captured fuel quantity gauge reading. The position of the fuel valves from the wing section is consistent only with fuel being provided from one or both fuselage tanks when the engines flamed out. The left hand auxiliary tank was not the source of fuel. This combined with the captured left hand auxiliary tank fuel quantity gauge reading of 4000 lbs. indicates that the left hand auxiliary tank was not run empty. Furthermore, flight testing failed to result in any engine flameouts when the left hand auxiliary tank was run empty. These three pieces of evidence refute this scenario. Status of Scenario Number 1: Refuted.

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3.1.2 Scenario Number 2. Right Hand Fuselage Fuel Tank Run Empty

Scenario Details: (Variation A): Two variations leading to the right hand fuselage tank being run empty were originally presented. The first variation presumed that there were either right hand fuselage tank fuel quantity gauging/indicating problems or leaking/failed fuel valves.

Conclusion: Although it appears that the right hand fuselage tank was run empty (reference Scenario Number 2, Variation B), close correlation of the calculated fuel burn with the captured readings on the recovered fuel gauges suggest that there was neither fuel quantity gauging/indicating problems or leaking/failed fuel valves. If either of these had occurred, the calculated fuel burn (i.e., 8400 lbs) would not correlate as closely with the actual fuel usage (i.e., 8000 lbs). Status of Scenario Number 2, Variation A: Refuted.

Scenario Details (Variation B): The second way to run the right hand fuselage tank empty may have occurred as follows. For an unknown reason, the entire sortie, including taxi, takeoff, climb and cruise, were flown while crossfeeding all four engines from the right hand fuselage tank. To fly this profile requires approximately 8400 lbs. of fuel, 400 lbs. more than that believed to be in the right hand fuselage tank. With fuel quantity gauging/indicating tolerances, it is possible that 8000 lbs. indicated really equated to 8400 lbs. actual and the right hand fuselage tank is now empty. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the left hand auxiliary tank and the same time when unexplained torque fluctuations occur. If the switch to the left hand auxiliary tank was not made, the fuel panel warning/caution lights not seen or believed, and the main tank pumps "OFF," the right hand fuselage tank would have been run empty. This would have allowed pressurized cabin air to enter the fuel supply manifold, via either the empty left hand or right hand fuselage tank, which worked its way out to all four engines. We believe that this scenario would be valid within fuel system tolerances if the crew used tank-to-engine fuel in the normal manner on the ground and for takeoff. This would imply slightly more fuel on board at the start or slightly less used during the mission. We do not believe that every minute of ground time would have to have been fueled from the fuselage tank.

Five pieces of new evidence directly impact this scenario. First, the positions of the fuel valves in the wing section are consistent only with fuel being provided from one or both of the fuselage tanks when the engines flamed out. Three main tank crossfeed valves (#1, 2, and 3) were recovered in the open position. The #4 main tank crossfeed valve was not recovered. The crossfeed separation valve, the right external tank crossfeed valve, and the right external dump valve were also found in the open position. These valve positions are consistent with fueling all four engines from the fuselage tank(s). All of the crossfeed valves are motor driven gate valves that require Essential DC power to be driven open or closed. They will remain in their last powered position because electrical power is required to open or close them. The internal design makes them non-susceptible to repositioning during impact. No electrical power was available after the last engine flameout. Additionally, the following valves were found closed: #1 and #2 dump valves, crossfeed primer valve, left hand auxiliary crossfeed valve, left hand auxiliary dump valve, left hand external crossfeed valve, left hand external dump valve, left hand bypass valve,

right hand auxiliary crossfeed valve, right hand bypass valve, off load valve, right hand dump valve, and the right hand aerial refueling valve. All of these valve positions are consistent only with fueling all four engines from the fuselage tank(s).

The second piece of evidence is the four fuselage fuel quantity gauges. There are two gauges for each fuselage tank, the primary in the cockpit on the auxiliary fuel panel, and a second gauge on the aft side of the fuselage tank cradle. The left hand fuselage tank fuel quantity gauges both indicated 600 lbs. The right hand fuselage tank fuel quantity gauges both indicated 300 lbs. Based on technical data, the BAR considers the right tank to be empty, and the left tank to be empty or nearly empty.*

The third piece of evidence that impacts this scenario is the #1 main fuel tank quantity gauge and the left auxiliary fuel quantity gauge. The left auxiliary fuel quantity gauge indicated 4000 lbs. and the #1 main tank fuel quantity gauge indicated 7000 lbs. These two findings, together with the empty or nearly empty fuselage gauge readings, are consistent with the fuel usage sequence postulated in this scenario. The implication of this fuel usage pattern is that the fuselage tank became empty just at the time when all four engines flameout.

The BAR has no physical evidence that proves the aircraft was fueled with 8000 lbs. of fuel in the right hand fuselage tank. The crew chief testified that he fueled 8000 lbs. in the right hand fuselage tank. He also testified that the manual shutoff valve to the left hand fuselage tank was closed. The BAR confirmed maintenance discrepancies that limited the use of either external tank and excluded the use of the right hand auxiliary tank. The BAR also discovered that a discrepancy in the indicating system of the left hand fuselage tank had been cleared two days before the mishap. This last observation is in conflict with the original BAR report. This scenario was originally written with the assumption that the left hand fuselage tank was not useable. The discovery of the cleared discrepancy does not alter the validity of the scenario; it simply expands it. The core issue of this scenario is independent of which fuselage tank used. Whether the left or right (or both) fuselage tank(s) runs dry, with the main boost pumps off, the inevitable result is the loss of all four engines.

Fourth, the cockpit fuel panel revealed that the crew moved the main tank crossfeed valve switches from the "crossfeed positions" to the "tank-to-engine positions" some time after the loss of power. The switch positions on the recovered fuel panel do not match the actual valve position because no electrical power was available to move the motor operated main tank crossfeed valves. This would be consistent with the crew recognizing the fuel component of the mishap and

* Aircraft fuel quantity gauges are not 100 % accurate, and there are several pertinent references in the operational technical manuals. Operational guidance (1C-130(H)H-1, Section 7) states that the fuselage tank empty light "...will blink on and off when the quantity drops to approximately 750 lbs." It also limits gauge accuracy to +/- 4% of the indication and +/- 2% of full scale gauge capacity. For the right tank (which indicated 300 lbs.) the range is 48-552 lbs. For the left tank (which indicated 600 lbs) the range is 336-864 lbs. Additionally, guidance in the 1C-130(H)H-1 states that the fuel gauges should be considered accurate only when straight and level (i.e., 3 degrees of roll, and a level pitch attitude). At the time of power loss King 56 was level with 0-9 degrees of bank. Tests conducted at Moody AFB GA on 5 Aug 98 showed the following results. The fuselage tank empty light began flickering when the cockpit fuselage fuel quantity gauge indicated 300 lbs. and came on steady when the gauge read 250 lbs. Corresponding tank gauges were 100 lbs. higher in each case.

attempting belatedly to close the main tank crossfeed valves.

It was technically impossible to verify the operating status of the four main tank boost pumps at the time of power loss. This is because the pumps were de-energized for the last 16 minutes of flight, and there would be no witness marks caused by the pumps moving parts during the impact sequence. Analysis of the fuel panel could not determine the positions of the main tank fuel boost pump switches. Therefore there is no physical evidence to clarify main fuel boost pump status at the time of power loss. Tests conducted on all of the recovered boost pumps (excluding the dump pumps) verify that the pumps were operational at the time of the mishap.

Fifth, the overhead edge light rheostat on the copilot's side shelf was found in the nearly full bright position. Similarly the copilot's instrument light rheostat was also nearly full bright. On the pilot's side panel, the pilot's instrument lights and the engine instrument lights are nearly full bright. These four rotary knob positions are consistent with very high levels of light in the cockpit. Additionally, the survivor testified that the mishap engineer was reading a book, just before the mishap sequence began. These data support high light levels in the cockpit. Such light levels would have the effect of making caution lights very difficult to see, especially if the caution and warning lights were dimmed. High light levels make it easier to believe that the crew might not have seen illuminated low pressure or tank empty lights.

These data must be considered in light of previously presented evidence that directly impacts this scenario.

First, the cockpit voice recorder tape clearly records two separate comments relating to deteriorating fuel flow. Clearly this is consistent with a fuel-related problem.

Second, the DFDR records stable RPMs while the torque was surging on all four engines. This is consistent with cockpit indications on engines that flameout due to fuel starvation.

Third, four previous incidents (identified in Section 5 of the BAR Report) originally thought to be synchrophaser system induced RPM rollbacks, were extensively investigated by direct interviews with the aircrew involved. This produced additional information that contradicted the earlier findings and established these incidents to be fuel starvation, caused by main tank boost pumps being turned off. Interviews also uncovered two previously unrecognized operator techniques that involved turning the boost pumps off. One was part of a pre-takeoff gravity fuel flow check while the other was an unpublished fuel management technique for use of fuselage tank fuel. Testimony from 304th Rescue Squadron, Portland IAP OR, flight engineers was that this in-flight technique was not used or taught in the squadron. Additionally, no one interviewed had any knowledge of the mishap flight engineer using the in-flight technique.

Fourth, Flight Tests conducted at Edwards AFB Flight Test Center validate this scenario and produced multiple engine flameouts, with indications in the cockpit consistent with the DFDR data from King 56. The tests showed that a key element in this scenario is that all four main tank boost pumps must be off. Without the main boost pumps off, engines did not flameout. These test results are consistent with this scenario.

Fifth, air injector tests conducted at Little Rock AFB involved injecting air into an operating engine's fuel supply. The air injection caused actual power loss, as indicated by torque and TIT reductions. These indications were similar to the indications observed on King 56's DFDR tape. RPMs were affected only subsequent to the torque reductions, again consistent with the DFDR tapes. These data are consistent with this scenario.

Finally, there is a preponderance of evidence, in the form of physical evidence, test results, historic records, and technical analysis, that are discussed in this report and in the original BAR report that refute other scenarios. The 10 pieces of evidence cited above strongly support this scenario. No evidence detracts from or refutes this scenario.

Status of Scenario 2, Variation B: Beyond reasonable doubt, the BAR concludes this scenario was the cause of the King 56 mishap.

DEFICIENCY: Guidance to aircrews did not clearly discuss the dangers associated with the fuselage tank and the risks associated with the introduction of pressurized air into the fuel system. Once the dangers were understood, the Air Force implemented operational changes to mitigate the risk.

> RECOMMENDATION: WR-ALC/LB evaluate the feasibility of engineering modifications to the C-130 fuel system to eliminate this risk.

3.1.3 Scenario Number 3. Insufficient Fuel Manifold Priming

Scenario Details: The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. A switch from the left hand auxiliary tank to the right hand fuselage tank necessitates that the crossfeed manifold, the right external tank manifold, the refuel/dump manifold, and the fuselage tank manifold be primed, or purged of air. If any significant amount of air remained after priming, it may cause the engines to flameout.

Conclusion: Two new pieces of evidence impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The position of the fuel valves from the wing section is consistent only with fuel being provided from one or both fuselage tanks when the engines flamed out. The fuselage tank fuel quantity gauges indicate that one or both fuselage tanks had already been successfully used to exhaustion, not that one of them was about to become the source of crossfed fuel. Lastly, this scenario is not corroborated by the results of flight testing. Flight testing clearly showed that when improper priming was performed, the engines momentarily lost power, fully recovered, and in no case flamed out. These last two

pieces of evidence refute this scenario. Status of Scenario Number 3: Refuted.

3.1.4 Scenario Number 4. Right Hand Fuselage Fuel Tank Pump(s) Failure

Scenario Details: With the preceding fuel load in Table 2-1, it is presumed that the engines fed from their respective main tanks for approximately the first 10 minutes of flight. For the remaining 10 minutes of climb and roughly the next 36 minutes of cruise, it is postulated that the engines were fed fuel from the left hand auxiliary tank. Once the left hand auxiliary tank was emptied, it is presumed that a successful transition to the right hand fuselage tank was accomplished. At one hour and 24 minutes into the flight, it is presumed that the right hand fuselage fuel tank pump(s) failed--the same time when the unexplained torque fluctuations occur. See Table 3-2 for fuel-related details about each phase of the sortie for this scenario. It is also worthy to note that the left hand auxiliary tank may not have been used at all in favor of the right hand fuselage tank during climb and cruise. In this case the right hand fuselage tank would have burned 6200 lbs. of fuel when the pump(s) failed.

	Time (minutes)	Fuel Used (k lbs)	Fuel Source, Duration and Quantity Used
Start, Taxi	15	0.75	Tank-to-Engine, 15 min, 750 lbs
Takeoff	2	0.30	Tank-to-Engine, 2 min 300 lbs
Climb	20	2.35	Tank-to-Engine, 10 min, ~1150 lbs. then Left Hand Auxiliary, 10 min, ~1200 lbs
Cruise	64	5.00	Left Hand Aux, 36 min, ~2800 lbs. then Right Hand Fuselage, 28 min, ~2200 lbs

Table 3-2. Fuel Burn Profile for Scenario Number 4

Conclusion: Two new pieces of evidence impact this scenario -- the final powered position of the fuel valves from the wing and the results of the teardown of the fuselage pumps. The position of the fuel valves from the wing section indicate one or both fuselage tanks were the source of fuel when the engines flamed out. However, all four pumps were recovered from the fuselage tanks, two from each tank, and their teardown revealed nothing abnormal. They were then reassembled and successfully run. This last piece of evidence refutes this scenario. Status of Scenario Number 4: Refuted.

3.1.5 Scenario Number 5. Left Hand Auxiliary Fuel Tank Pump Failure

Scenario Details: This scenario is a variation of scenario number 4. This scenario presumes that all four engines are being crossfed from the left hand auxiliary tank when the pump in that tank fails. To get to this point, a fuel burn similar to that of scenario number 1 could have been used except that the transition to left hand auxiliary tank would have been delayed beyond the 13 minutes after level off cited for scenario number 1.

Conclusion: Three new pieces of evidence impact this scenario -- the final powered position of

the fuel valves from the wing section, the captured fuel quantity gauge readings, and results of the left hand auxiliary tank pump teardown. The position of the fuel valves from the wing section indicate one or more fuselage tanks, not the left hand auxiliary tank, was the source of fuel when the engines flamed out. The left hand auxiliary fuel tank still contained 4000 lbs. which indicates it had not been used. And finally, the teardown of the left hand auxiliary tank pump revealed nothing abnormal. It was then reassembled and successfully run. All of these facts refute a left hand auxiliary tank pump failure scenario. Status of Scenario Number 5: Refuted.

3.1.6 Scenario Number 6. Undetected Fuel Leak

Scenario Details: This scenario assumes that an undetected fuel leak existed in the refuel/dump manifold. In this scenario, the engines are fed normally from their respective main tanks during takeoff and some portion of climb. The transition to and use of the left hand auxiliary tank is successful. The transition to the right hand fuselage tank is also successful. (Note: The refuel/dump manifold is not pressurized when crossfeeding from the left hand auxiliary tank but is pressurized when crossfeeding from the right hand fuselage tank.) However, at some point, a large fuel leak develops in the refuel/dump manifold outside of the wing (i.e., aft of the aft spar). Unbeknownst to the crew, this leak quickly drains the right hand fuselage tank as well as all four main tanks. With no more fuel on board, all four engines flameout.

Conclusion: Two new pieces of evidence impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The positions of the fuel valves from the wing section are consistent with a pressurized refuel/dump manifold. However, the fact that there is no fuel missing from either the left hand auxiliary tank or the #1 main tank is inconsistent with the occurrence of this scenario. US Coast Guard and US Navy observations of a petroleum slick on the ocean's surface during rescue and recovery efforts are also inconsistent. These latter two pieces of evidence refute this scenario. Status of Scenario Number 6: Refuted.

3.1.7 Scenario Number 7. Fuel Dump Valve(s) Stuck Open

Scenario Details: This scenario is a variation of scenario number 6 and assumes that one or both of the fuel dump valves are stuck open. In this scenario, the engines are fed normally from their respective main tanks during takeoff and some portion of climb. The transition to and use of the left hand auxiliary tank is successful. The transition to the right hand fuselage tank is also successful. However, with the refuel/dump manifold now pressurized, fuel begins to be dumped overboard via one or both dump masts near the wing tips. Unbeknownst to the crew, this uncommanded fuel dumping quickly drains the right hand fuselage tank as well as all four main tanks. With no more fuel on board, all four engines then flameout.

Conclusion: Three new pieces of evidence impact this scenario -- the final powered position of the fuel valves from the wing section, the captured fuel quantity gauge readings, and the final powered position of the right hand dump valve. The positions of the fuel valves from the wing section are consistent with a pressurized refuel/dump manifold. However, the fact that there is no fuel missing from either the left hand auxiliary tank or the #1 main tank is inconsistent with the

occurrence of this scenario. The right hand dump valve recovered in a closed position is also inconsistent. Lastly, US Coast Guard and US Navy observations of a petroleum slick on the ocean's surface during rescue and recovery efforts is also inconsistent. These latter three pieces of evidence refute this scenario. Status of Scenario Number 7: Refuted.

3.1.8 Scenario Number 8. Refuel/Dump Line Rupture

Scenario Details: This scenario is the same as scenario number 6 except that the leak is assumed to be much larger. The leak is so large, that when combined with a presumed low pressure area just behind the aft spar, fuel is actually pulled/siphoned from the refuel/dump manifold to such an extent that an insufficient fuel flow is available to the engines and they flameout. This occurs even though there is still a significant amount of fuel remaining in the right hand fuselage tank and main tanks.

Conclusion: There is no new physical evidence that directly impacts this scenario. Although this scenario cannot be definitively refuted with physical evidence, engineers from WR-ALC stated even if the refuel/dump manifold were completely severed, four operating main tank fuel pumps would still have sufficient capacity to support uninterrupted engine operation. Additionally, there is no precedent for catastrophic refuel/dump manifold failure. These data together argue that this scenario is extremely unlikely. Status of Scenario Number 8: Highly Improbable.

3.1.9 Scenario Number 9. Water in Right Hand Fuselage Fuel Tank

Scenario Details: Water can be inadvertently introduced into or accumulate in fuselage tanks. The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. Portland had experienced extremely rainy weather in the days prior to the mishap. This rainfall may have worked its way into a fuel-servicing vehicle that was dispatched to service the King 56. Or equivalently, several temperature cycles during extremely humid conditions may have resulted in significant condensation inside the fuselage tanks. If this water was not drained from the right hand fuselage tank, it may have been sent to the engines resulting in four flameouts.

Conclusions: Two new pieces of evidence impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The positions of the fuel valves from the wing section are consistent with fuel being provided from one or more fuselage tanks. However, all the fuselage tank quantity gauges indicate that fuel in the fuselage tanks was successfully utilized. Additionally, water in a fueled fuselage tank would have been detected during the positive fuel check performed during the Taxi Checklist or when the tank was first selected in flight (water being heavier than JP-8 fuel). Evaluations of fuel from the tank farm at Portland and the servicing truck that supplied fuel to King 56 revealed no

contamination. Finally, other aircraft fueled from the same truck as King 56 flew successfully. There is no supporting evidence for this scenario. Status of Scenario Number 9: Refuted

3.1.10 Scenario Number 10. Water in Left Hand Auxiliary Fuel Tank

Scenario Details: This scenario is a variation of scenario number 9. Water can be inadvertently introduced into or accumulate in auxiliary tanks. Portland had experienced extremely rainy weather in the days prior to the mishap. This rainfall may have worked its way into a fuel-servicing vehicle that was dispatched to service King 56. Or equivalently, several temperature cycles during extremely humid conditions may have resulted in significant condensation inside the auxiliary tank. If this water was not drained from the left hand auxiliary tank, it may have been sent to all of the engines resulting in four flameouts.

Conclusion: Two new pieces of evidence impact this scenario -- the captured fuel quantity gauge readings and the final powered position of the fuel valves from the wing section. The captured 4000 lbs. reading for the left hand auxiliary fuel tank gauge indicates the tank had not yet been used. Therefore, it is possible that water could be sitting at the bottom of the tank. However, the position of the fuel valves from the wing section indicate one or both fuselage tanks, not the left hand auxiliary tank, was the source of fuel when the engines flamed out. Additionally, water in the left hand auxiliary tank would have been detected during the positive fuel check performed during the Taxi Checklist or when the tank was first selected in flight (water being heavier than JP-8). Evaluations of fuel from the tank farm at Portland and the servicing truck that supplied fuel to King 56 revealed no contamination. Finally, other aircraft fueled from the same truck as King 56 flew successfully. There is no supporting evidence for this scenario. Status of Scenario Number 10: Refuted.

3.1.11 Scenario Number 11. Contaminated Fuel

Scenario Details: Contaminated fuel has caused aircraft crashes in the past. This contamination can come from the aircraft or an outside source. Regardless of the source, fine particulate contamination is of concern in this scenario. It is postulated that fine particulates could work their way past the aircraft fuel filters, into the engine fuel controls, and over time, adversely affect the fuel metering valves inside the fuel controls. In certain circumstances, this could lead to engine flameouts.

Conclusions: Two new pieces of evidence impact this scenario -- the results of the teardown for the additional three engines and the internal inspection of the five recovered fuel tanks. None of the three additional recovered engines showed any signs of contamination. This is also true for the first engine originally recovered by the Safety Investigation Board. Additionally, inspection of the #2 main tank, both left and right auxiliary tanks, and both left and right fuselage tanks revealed no evidence of any significant contamination or foreign objects. There is no supporting evidence for this scenario. Status of Scenario Number 11: Refuted.

3.1.12 Scenario Number 12. Right Hand Fuselage Fuel Tank Manual Isolation Valve Closed

Scenario Details: The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. The manifold that connects the fuselage tanks to the aircraft incorporates three manual isolation valves. One isolation valve simultaneously isolates both fuselage tanks from the aircraft fuel system. The other two valves only isolate one tank each. Since the left hand fuselage tank was reportedly not fueled for the mishap sortie, the left hand manual isolation valve may have been closed thereby isolating it from the aircraft fuel system. However, assuming that the right hand fuselage tank was properly fueled, and that somehow its manual isolation valve was closed either instead of or in addition to the left manual isolation valve, fuselage fuel would be trapped and not be available.

Conclusion: Two new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The positions of the fuel valves from the wing section indicate that one or both fuselage tanks were the intended source of fuel when the engines flamed out. Given this fact two possibilities exist; either the flight engineer had just finished using fuselage tank fuel or he was just now intending to use it. If the flight engineer had just finished using fuselage tank fuel, then there could not have been an inadvertently closed manual shutoff valve. If the flight engineer was just now intending to use fuselage tank fuel, it is believed that the flight engineer would surely have made the connection with the transition to a new tank and the engine power loss now occurring. With the connection recognized, it is believed the flight engineer would quickly undo that just done and sought another source of fuel. The near-empty readings from the fuselage tank gauges are consistent with the successful usage of fuselage tank fuel. These facts and logic are inconsistent with a closed manual shutoff valve scenario. Status of Scenario Number 12: Refuted.

3.1.13 Scenario Number 13. Cabin Pressurization Procedure

Scenario Details: This procedure involves using cabin pressure, not fuselage tank pumps, to move fuel from the right hand fuselage tank to the engines. The methodology to perform this procedure is covered in T.O. 1C-130(H)H-1, Section 7. The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. Again, if all the main tank pumps were off, not just a maximum of two allowed by the Section 7 procedure, and the left hand fuselage tank manual isolation valve open, pressurized cabin air would be sent through the fuel supply manifold via the empty left hand fuselage tank. If allowed

to persist long enough, this would result in four engine flameouts.

Conclusions: The crew could have been performing this procedure for one of two reasons: either there was a need to perform the procedure or it was being performed for training purposes. Two new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section and the results of the fuselage tank pump teardowns. There was not an operational need to perform this procedure because all the fuselage tank pumps were found to be fully functional -- that is, nothing unusual was found during their teardown and they were successfully run after reassembly. If the procedure were being performed for training, it was not being performed properly. The procedure allows for a maximum of two engines to be crossfeed at a time, but three main tank crossfeed valves were recovered in the open position. Additionally, if they were performing this procedure for training, then one could reasonably believe there would be some discussion on the interphone. There was none in the last 30 minutes of conversation recorded on the cockpit voice recorder. Lastly, if this procedure were being performed, the flight manual cautions the crew to be alert for fuel flow fluctuations and specifies recovery actions if they are observed. These data together argue that this scenario be refuted. Status of Scenario Number 13: Refuted.

3.1.14 Scenario Number 14. Wrong (i.e., Left Hand) Fuselage Fuel Tank Selected

Scenario Details. This scenario is a variation of scenario number 13. The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. If the flight engineer inadvertently turned on the left hand fuselage tank pump(s), instead of the right hand fuselage tank pump(s), the main tank pumps were "OFF," and the fuel panel warning/caution lights not seen or believed, then the engines could have flamed out due to pressurized cabin air entering the fuel supply manifold via the empty left hand fuselage tank.

Conclusions: Two new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The positions of the fuel valves from the wing section indicate one or both fuselage tanks were the intended source of fuel when the engines flamed out. However, all the fuselage tank fuel quantity gauges indicated very low quantities, indicating that one or both of them had been in use for some time. This is further corroborated by the captured readings on the #1 main tank gauge and the left hand auxiliary tank gauge. These facts are inconsistent with the wrong fuselage tank being selected. Status of Scenario Number 14: Refuted.

3.1.15 Scenario Number 15. Synchrophaser Failure

Scenario Details: For this scenario, the synchrophaser is presumed to have a single or multiple failure mechanism which results in four-engine flameouts. The C-130 fleet has experienced

numerous incidents involving uncommanded engine RPM rollbacks during flight (reference the 15 Jan 98 C-130 BAR Report, Section 5). These RPM reductions are characterized as momentary in nature, usually lasting only several seconds. Typically all four engines are affected simultaneously, and the maximum amount of RPM lost in the worst case is approximately four percent. There is some ambiguity as to the magnitude of any power loss because the torque gauges in the cockpit are known to provide erroneous readings when their electrical power source is fluctuating. The cockpit torque gauges are powered by the essential AC bus, the same bus powering the synchrophaser.

Fluctuations in essential AC power, essential bus generator failure, faulty/loose synchrophaser-related wiring, exposure of the synchrophaser to moisture, internal synchrophaser failures, or electromagnetic interference can result in four engine RPM rollbacks. All exact failure mechanisms are not known, but the RPM reductions may occur if the engines are in the normal or synchrophasing mode and erroneous signals reach the speed bias motor. The issue addressed by this scenario is whether this situation can deteriorate to engine flameout.

Conclusion: There is no new physical evidence that directly impacts this scenario. However, the previous analysis of Digital Flight Data Recorder data is still valid. It indicates that all four propeller RPMs were within governed limits throughout the event sequence until each individual engine torque dropped to zero or a negative value. At this point, there was insufficient torque produced by the engines to maintain full-governed propeller speed and therefore the RPM decreased individually as each engine lost torque output. This is consistent with properly functioning propeller governors and the synchrophasing system. It is inconsistent with the known history of synchrophasing system induced RPM rollbacks, where multiple simultaneous RPM change is the first symptom and is limited to 4%. System design, laboratory testing, and a long history of synchrophasing system operation all refute the theory that sychrophasing system failure can lead to single or multiple flameouts or that it was causal in the King 56 mishap. Status of Scenario Number 15: Refuted.

3.1.16 Scenario Number 16. Temperature Datum System Failure

Scenario Details: Each temperature datum system has the ability to take and put fuel to its respective engine. Based upon throttle position, specific fuel properties, and measured engine turbine inlet temperature, each temperature datum amplifier commands its temperature datum valve to take or put fuel to the engine so that targeted turbine inlet temperature is achieved. It is postulated that fluctuations in essential AC and/or DC power, essential bus generator failure, or electromagnetic interference can result in four engine power losses. All exact failure mechanisms are not known, but engine power losses may occur if too much fuel is taken from the engines. In the extreme case, it is suggested that the temperature datum systems might cause engines to flameout.

Conclusion: Three new pieces of evidence specifically impact this scenario -- the teardown results from the #1, #2, and #3 engines, the identification of the three temperature datum amplifiers, and the results of the spectral analysis for the cockpit voice recorder. The temperature datum valves are captured by an internal brake mechanism in the last position commanded by the temperature

datum amplifier when electrical power to the engine is lost. Temperature datum valves from #1, #2, and #3 engines were discovered in a "put" position. In other words, the systems were providing an increased fuel flow due to engine turbine inlet temperature being lower than the value commanded by throttle position. This is inconsistent with the theory that the observed engine flameouts might have been attributable to the aircraft's temperature datum systems being driven erroneously to maximum "take" conditions.

The second piece of new evidence involves the recovered temperature datum amplifiers. The three newly recovered amplifiers were manufactured by Bendix. Tests on the Bendix temperature datum amplifier revealed it to be relatively unaffected by supply voltage drops.

The third piece is the results of the audio spectral analysis for the cockpit voice recorder. That analysis revealed that electrical system frequency remained steady at approximately 400 Hz throughout the mishap sequence, even during engine flameouts which produced generator load switching. This means that the electrical system stability was adequate to preclude adverse affects on all four temperature datum amplifiers.

These new data must be considered in light of earlier data. The fourth temperature datum amplifier, recovered in the earlier recovery mission was of the Raven type and its temperature datum valve was in approximately a 7% "take" position.

It is important to note that the four temperature datum valve settings were not identical, in fact one (#4) was substantially different. This refutes the theory that all four temperature datum amplifiers were acting in unison, driven by some external influence to a position which could produce a four engine flameout. In addition, history and a substantial amount of testing indicates it is extremely unlikely a temperature datum system failure could result in four engine flameouts. These data together, the preponderance of "put" signals, the presence of Bendix temperature datum amplifiers, and the nonidentical settings on the temperature datum valves refute this scenario. Status of Scenario Number 16: Refuted.

3.1.17 Scenario Number 17. Improper Common Maintenance Action

Scenario Details: This scenario presumes that there was some common, routine maintenance that was performed on the aircraft that could have adversely affected all four engines. Examples might include a periodic engine filter replacement where filters with too fine a "mesh" were installed. As the aircraft flew, these filters became clogged by particulate matter normally allowed to pass through the proper filters, eventually sufficiently restricting fuel flow leading to engine flameouts. Another scenario may include the installation of the proper filters, but their housings were improperly reassembled leading to nearly simultaneous failure and loss of fuel flow. A final example may include engine oil changes where an inadequate or excessive amount of oil was added to the engines.

Conclusion: One new piece of evidence directly impacts this scenario -- the teardown results of the three additional engines. The teardown of these three engines revealed no evidence of improper maintenance. This is also true for the first engine recovered by the Safety Investigation

Board. This scenario is also rebutted by the results of the Preflight Inspection performed on 21 Nov 96 and the results of the Through Flight Inspection performed on 22 Nov 96. The preflight and thru-flight inspections found nothing significant. Additionally, no common maintenance was performed between the morning and evening sorties on 22 Nov 96. The only maintenance performed between the morning and evening sorties was the replacement of two Integrated Display Control Units. Their replacement was deemed unrelated to the King 56 mishap. There is no supporting evidence for this scenario. Status of Scenario Number 17: Refuted.

3.1.18 Scenario Number 18. Engine Icing

Scenario Details: This scenario presumes that icing conditions were encountered which were either not detected or acted upon. This could be due to a failure of either the ice detection or the anti-icing systems. If ice was allowed to build on the aircraft engines, it is postulated that pieces of ice break free, are ingested by the engines, and flame them out.

Conclusion: One new piece of evidence directly impacts this scenario -- the teardown results of the three additional engines. The teardown of these three engines revealed no evidence of ice induced damage to any of the engines' blades. This is also true for the #4 engine. This scenario is also rebutted by the lack of icing conditions at or near King 56's cruise altitude. There is no supporting evidence for this scenario. Status of Scenario Number 18: Refuted.

3.1.19 Scenario Number 19. Wrong (i.e., Left Hand) Fuselage Fuel Tank Filled

Scenario Details: This scenario is a variation of scenario number 14. This scenario assumes that maintenance filled the left hand fuselage tank instead of the right hand one and that all three manual isolation valves are open. The fuel burn for this scenario is assumed to be the same as previously described in scenario number 1. The engines fed from their respective main tanks for approximately the first 33 minutes of flight. This is followed by 51 minutes of all four engines being fed fuel from the left hand auxiliary tank. At this point, the aircraft is one hour and 24 minutes into the flight--the time when the flight engineer needs to use fuel from the right hand fuselage tank and the same time when unexplained torque fluctuations occur. See Table 3-1 for fuel-related details about each phase of the sortie for this scenario. Again, it is presumed the main tank pumps are off and that there is some crossed wiring such that the fuel in the left hand fuselage tank is indicated on the right hand fuselage tank quantity gauge in the cockpit. When the flight engineer intends to crossfeed "fuel" from the right hand fuselage tank in the usual way, pressurized cabin air enters the fuel supply manifold, via the empty left hand fuselage tank, resulting in four engine flameouts.

Conclusions: Two new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section and the captured fuel quantity gauge readings. The positions of the fuel valves from the wing section indicate that one or both fuselage tanks were the intended source of fuel when the engines flamed out. Given this fact, two possibilities exist; either the flight engineer had just finished using fuselage tank fuel or he was just now intending to use it. If the flight engineer had just finished using fuselage tank fuel, then it is believed there were no problems with the fuselage tank fuel system. If the flight engineer was just

now intending to use fuselage tank fuel, it is believed that the flight engineer would surely have made the connection with the transition to a new tank and the engine power loss now occurring. With the connection recognized, it is believed the flight engineer would quickly undo that just done and sought another source of fuel. The near-empty readings from the fuselage tank gauges are consistent with the successful usage of fuselage tank fuel. These facts and logic are inconsistent with a wrong fuselage tank filled scenario. Status of Scenario 19: Refuted.

3.1.20 Scenario Number 20. Synchrophaser and Temperature Datum Failures

Scenario Details: This scenario is a combination of the synchrophaser failure and temperature datum system failure scenarios detailed separately as scenarios number 15 and number 16. In this case, it is presumed that there is an unknown failure mode such that the combined interaction of both systems reduces both engine RPM and fuel flow in such a manner as to cause all engines to flameout. Another possibility is that the combined effect would reduce RPM to the point of opening of the acceleration bleed valves, reducing compressor efficiency so that the total effect of all events results in engine flameouts.

Conclusions: Two new pieces of physical evidence and analysis impact this scenario. Three recovered temperature datum valves were in the "put" mode -- meaning they were attempting to add fuel to the engines. Also, three of the associated temperature datum amplifiers were Bendix units which were relatively unaffected by low voltage during precise ground testing. This combined with the physical evidence from the Digital Flight Data Recorded showing propeller RPMs were with governed limits until insufficient torque was available, refute the theory that a combination of synchrophaser failure and temperature datum amplifier failure could have produced multiple engine flameouts. In addition, audio spectral analysis of the cockpit voice recorder tape revealed that electrical system frequency remained steady at approximately 400 Hz throughout the mishap sequence, even during engine failures, which produced generator load switching. This means that the electrical system stability was adequate to preclude adverse combined effect on the synchrophaser and temperature datum amplifier systems. Constant 400 Hz output also indicates that the generator RPM and hence engine and propeller RPMs were also steady within allowable limits until each engine flamed out and stopped producing sufficient torque. Engine #4 temperature datum amplifier was a Raven unit and its temperature datum valve was recovered in approximately a 7 percent "take" position. This further refutes the theory that all four temperature datum amplifiers were acting in unison, driven by some external influence to a position which could produce a four engine flameout. Since both synchrophaser and Temperature Datum System theories were refuted separately in other scenarios, it is consistent to reject the combined scenario. Status of Scenario 20: Refuted.

3.1.21 Scenario Number 21. Plugged Vent System

Scenario Details: This is a new scenario developed after the 15 Jan 98 C-130 BAR report. This scenario presumes that all the fuel tank vents are somehow blocked. If this occurred, the fuel tanks would initially begin to drain but this action would begin to draw a vacuum on each tank providing fuel to the engines. At a certain point it is postulated that the engine driven boost pumps could no longer overcome this ever-increasing vacuum and continue to draw fuel.

Eventually the fuel tanks would want to "burp" assuming they first did not first fail structurally. If the tanks "burped" and drew air in through an engine fuel supply manifold, this incoming air could perhaps quickly run through the crossfeed manifold and out to the other engines resulting in four engine flameouts.

Conclusion: Three new pieces of evidence specifically impact this scenario -- the final powered position of the fuel valves from the wing section, the captured fuel quantity gauge readings, and the results of the inspection of the vent systems for the #2 main tank and the left and right auxiliary tanks. The positions of the fuel valves from the wing section indicate that one or both fuselage tanks were the intended source of fuel when the engines flamed out. However, all the fuselage tank fuel quantity gauges indicated very low quantities, indicating that one or both of them had been in use for some time. This is inconsistent with the fuselage tank vent system being plugged. All of the wing fuel tanks have their own vent system and none of the vent systems for the three tanks recovered revealed any evidence that they were plugged or partially obstructed in way. The timing for a plugged vent system scenario is also very remote since it must occur after refueling. Had the vents been plugged prior to refueling, structural failure of one or more main tanks would have occurred during the refueling operation. Since this did not happen, this scenario requires that the vent systems be plugged after the refueling following the morning sortie but before evening sortie on 22 Nov 96. This is an extremely remote possibility. These facts and logic are inconsistent with a plugged vent system scenario. Status of Scenario 21: Refuted.

Summary: Because the foregoing discussion covering all the scenarios is extremely lengthy, a consolidated summary is presented in Table 3-3. This table succinctly summarizes which pieces of evidence and data corroborate or refute each scenario. A tremendous amount of information has been consolidated into a very concise, quick reference; however, it may be necessary to reference other sources of information since some pertinent information may not be included.

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Table 3-3 Scenario Evidence and Data Quick Reference

EVIDENCE & DATA \ SCENARIO #	1	2a	2b	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
EVIDENCE																						
CVR - General Discussions, Fuel Flow Comments	C	C	C	CR	C	C	C	C	C	R	R	C	CR	CR	CR	R	~	C	R	CR	~	C
DFDR - Torque, RPM, Seq v. Sim Flameouts	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	R	~	C	C	C	R	C
Aircraft Records	~	C	C	~	~	~	~	~	~	~	~	~	~	~	~	C	C	R	~	C	C	~
Weather	~	~	~	~	~	~	~	~	~	C	C	~	~	~	~	~	~	~	CR	~	~	~
Radar Data - Departure & End of Sortie	R	~	~	~	~	~	~	~	~	~	~	~	~	~	~	R	R	~	~	~	R	~
Fuel Sample Results	~	~	~	~	~	~	~	~	~	R	R	R	~	~	~	~	~	~	~	~	~	~
#4 Engine Teardown Results	~	~	~	~	~	~	~	~	~	~	~	R	~	~	~	~	R	R	R	~	R	~
HISTORICAL DATA																						
Previous Main Tank Pump Switch OFF Events	C	C	C	~	C	C	~	~	~	~	~	~	C	C	C	~	~	~	~	C	~	C
Other Previous Related Events	~	~	~	C	~	~	C	C	R	~	~	C	~	~	~	C	~	~	C	~	C	~
TEST DATA																						
1988 LM-Allison-HStd Synchro-TD Test	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	R	R	~	~	~	R	~
1997 Allison TD-Low Voltage Test	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	R	~	~	~	~	~
1997 Allison Air Injection Test	C	C	C	C	C	~	~	~	~	~	~	~	C	C	C	~	~	~	~	C	~	~
1997 Edwards AFB Ground Test	C	~	~	~	~	R	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
1997 Edwards AFB Flight Test	R	C	C	CR	C	R	~	~	~	~	~	~	C	C	C	~	~	~	~	C	~	~
1997 Independent Synchrophaser FMEA	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	R	~	~	~	~	R	~

SALVAGED COMPONENTS \ SCENARIO #	1	2a	2b	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Final Powered Position of the Fuel Valves	R	C	C	C	C	R	C	CR	C	C	R	~	C	C	C	~	~	~	~	C	~	~
Captured Fuel Quantity Gauge Readings	R	R	C	R	~	R	R	R	~	R	C	~	R	~	R	~	~	~	~	R	~	R
L&R Hand Fuselage Tanks Inspection Results	~	~	~	~	~	~	~	~	~	~	~	R	~	~	~	~	~	~	~	~	~	R
Fuel Pump Teardown Results	C	C	C	C	R	R	C	C	C	C	C	~	~	R	~	~	~	~	~	~	~	~
#1, #2 and #3 Engine Teardown Results	~	~	~	~	~	~	~	~	~	~	~	R	~	~	~	~	R	R	R	~	R	~

C = Corroborates Scenario
R = Rebuts Scenario
~ = Not Applicable to Scenario

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Section 4.0

Conclusion

Based upon the positional information obtained from the recovered fuel valves (e.g., either open or closed), the captured readings obtained from the recovered fuel quantity gauges, and the flight test results (not covered here but discussed in the 15 Jan 97 C-130 BAR report), the C-130 BAR believes it is probable that King 56's engines sequentially flamed out as a result of fuel starvation. This condition occurred on King 56 most probably because the main tank pumps were in the "OFF" position when the right hand fuselage tank emptied. With this tank empty, pressurized cabin air was then allowed, via open fuel valves, to enter the fuel supply manifolds for the engines.

King 56 engines stopped due to fuel starvation as a result of improper fuel management procedures. The crew failed to correctly analyze the situation in time to take the appropriate corrective actions.

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Section 5.0

Recommendations

The following recommendations reflect the BAR team's analysis of discrepancies noted during the salvage operation and subsequent review of the data collected. These recommendations are found in the body of the addendum and are compiled here for quick reference.

1. The crossfeed primer valve had an improperly installed motor housing, giving the appearance the valve was open when actually closed. (Section 2.2.1.)

    RECOMMENDATION: WR-ALC/LB direct a one-time inspection of all valves with similar construction to the crossfeed primer valve to verify proper assembly and SA-ALC/LD redesign motor housing to prevent reoccurrence and update Technical Orders.

2. Several nonstandard practices were identified with the King 56 fuselage tanks. First, extraneous hardware was left in both fuselage tanks following an apparent improperly accomplished Time Change Technical Order (TCTO). Next, fleet-wide evidence suggests fuselage tanks are not being regularly drained of water, potentially leading to tank corrosion. The discovery of a coating of Corrosion Preventative Compound (CPC) in one tank is evidence of a nonstandard procedure resulting from unanticipated corrosion. (Section 2.2.5)

    RECOMMENDATION: WR-ALC/LB direct a one-time inspection of all fuselage tanks to ensure proper completion of TCTOs and check for corrosion and presence of foreign objects.

3. Guidance to aircrews did not clearly discuss the dangers associated with the fuselage tank and the risks associated with the introduction of pressurized air into the fuel system. Once the dangers were understood, the Air Force implemented operational changes to mitigate the risk. (Section 3.1.2)

    RECOMMENDATION: WR-ALC/LB evaluate the feasibility of engineering modifications to the C-130 fuel system to eliminate this risk.

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Appendix A

Evaluation of Wreckage Deemed Not Key to Cause

The following items were recovered but not considered to be a factor in the crash of King 56. Appendix B contains a complete listing of reports from the depots that analyzed these parts.

- Forward Wing Spar
- RH Wing Dump Valve
- RH Refueling Pod Shutoff Valve
- Bulkhead at RH OWS 283 and #4 Dump Pump
- Fuselage Fuel Tank Relay Panel
- Pilot's Instrument Panel
- Copilot's Instrument Panel
- Navigator's Control Panel
- Direction Finder Set
- Pressurization Panel
- GTC/Anti-Icing/Bleed Air Panel
- Electrical Panel
- Main AC Bus/ESS DC Bus Circuit Breaker Panel
- Emergency Water Jug

A.1 Forward Wing Spar. When this section of wreckage was first observed, the wing section had not yet been located. Considering the possibility that the wing section may never be found, this section of the aircraft was recovered in hopes of recovering some fuel valves attached to it. This section was readily identified as being a leading edge spar based upon the spacing of the vertical stiffeners on the forward side of the forward spar. Since the forward spar in front of the #1 and #2 dry bays were known to be part of the wing section, it was believed that either #3 or #4 dry bay fuel valves may be attached to this piece. If they were not attached the recovery and positive identification of this piece may better define a subsequent search area for these desired valves. This piece was positively identified as a section of forward wing spar, which runs from approximately RH OWS 320 to 420. Identification was made via part numbers ink-stamped on various parts as well as the tapering height of the spar. Unfortunately this portion of spar was too far outboard of the #4 dry bay to have any fuel valves attached to it.

A.2 Right Wing Dump Valve and Right Refueling Pod Shutoff Valve: A small portion of the right-hand aft spar was located with the above two valves still attached to it. Information from the valves' identification plates revealed: Dump Valve - body P/N Unk, S/N 1227; actuator P/N H1017-008, S/N 48 and Shutoff Valve - body P/N JC Carter 6301, S/N 6137; actuator JC Carter P/N 81145, S/N 10784. Visual inspection revealed that both valves were closed (their butterflies were fully closed, seated against their Teflon seals and the indicator/manual actuation lever arms on the bottom of the actuators were in the closed position). The closed position of these two valves rules out the possibility of the inadvertent fuel dump scenarios on the right wing from either the dump mast or the refueling pod.

A.3 Bulkhead at RH OWS 283 and #4 Dump Pump. The #4 Dump Pump (P/N 60-371C, S/N 9038) was visually examined. Nothing unusual was noted. It was sent to AFRL/MLS for teardown and analysis. Nothing unusual was found with the pump.

A.4 Fuselage Fuel Tank Relay Panel. The four electrical relays for the four fuselage fuel tank fuel pumps were recovered (e.g., one relay for each pump). The relays were still attached to their original mounting structure and still had some small segments of wire still attached to them. These relays were sent to AFRL/MLS where they were disassembled and analyzed for evidence which may provide clues as to which fuselage tank pump or pumps were running when the last engine flamed out and the ability to generate electrical power was lost. The design of the relays and the damage they suffered after impact made it impossible to determine what, if any, pumps were running when power was lost. There was no evidence of contact welding or other pre-mishap anomalies in any of the analyzed components that would have affected their operation.

A.5 Pilot's Instrument Panel: The following observations were made at the time of recovery. Detailed Depot analysis can be found in the reports listed in Appendix B. For each instrument where analysis was done, the results are briefly noted. The nature of the crash limited the information recovered from the instruments.

These switch positions cannot be considered reliable due to crew actions after electrical power loss, impact forces, or recovery efforts.

A.5.1 Magnetic Standby Compass (B-21): The compass was intact and rotated freely.

A.5.2 Accelerometer: The MA1 Accelerometer was intact. It provides instantaneous as well as maximum and minimum readings of G forces exerted on the aircraft. The gauge scale is from positive 4 Gs to negative 2 Gs. The accelerometer is designed for in flight use and does not accurately measure G forces during landing. The maximum pointer was at 4 Gs while the negative pointer was at greater than two Gs. The position of the main pointer was not recorded. Depot analysis revealed the main pointer at –0.4 Gs, maximum indicator at +3.8 Gs, and the minimum pointer at –2.0 Gs (pegged).

A.5.3 Pilot's Radar Indicator: This piece of equipment was missing and not recovered.

A.5.4 Clock: The pilot's clock was intact and indicated 7:02.

A.5.5 Airspeed Indicator: The indicator was intact. The airspeed indicator receives inputs from the pitot-static system. This unpowered instrument will continue to indicate after power is lost, and through out the crash sequence unless impact forces cause its indications to be captured. The maximum Airspeed indicator was at 316 kts, the airspeed pointer and vernier drum were indicating 402 kts. Depot analysis confirmed these observations, but concluded that the indications had not been captured.

A.5.6 Attitude Direction Indicator (ADI): The glass was intact, and the instrument indicated a left 20 degrees turn and approximately 1 degree nose up. Depot analysis indicates 22 degrees left

bank and 2 degrees nose up. The indicator was not captured and the indications could have changed as a result of impact forces.

A.5.7 Horizontal Situation Indicator (HAI-AQU-2/A): The HSI was intact but was encrusted and was difficult to see through its front glass. The Compass Card indicated 082 degrees, and the course arrow was approximately 161 degrees. Depot analysis confirmed these two items, and also determined:

Instrument	Indication
Compass Card	082 degrees
Course Arrow	161 degrees
Course Window	161 degrees
Heading Marker	162 degrees
Bearing Pointer	087 degrees
Range Indicator	Free to rotate (shutter in view)

A.5.8 Altimeter: The indicator was intact. The airspeed indicator receives inputs from the pitot-static system. This unpowered instrument will continue to indicate after power is lost, and through out the crash sequence unless impact forces cause its indications to be captured. The airspeed indicator was intact and the barometric pressure setting was 30.00. The pointer and drum indicated 25,440 ft. Depot analysis confirmed these data but indicated that the readings were not captured.

A.5.9 Vertical Velocity Indicator: The indicator was intact. The airspeed indicator receives inputs from the pitot-static system. This unpowered instrument will continue to indicate after power is lost, and throughout the crash sequence unless impact forces cause its indications to be captured. The instrument was intact and indicated 5600 feet per minute climb. Depot analysis indicated 6000 fpm climb and that the readings were not captured.

A.5.10 Radio Magnetic Indicator, UHF/VHF-DF: This instrument tends to retain its readings upon the loss of power. Impact forces can change the indications. The instrument was intact but the glass was smashed. The compass card read 052 degrees. Depot analysis indicate the #1 bearing pointer read 335 degrees, and the #2 bearing pointer read 040 degrees.

A.5.11 Flight Director Mode Selector Panel (FDMS): This panel controls the input sources for the Horizontal Position Indicator and the Attitude Indicator. The panel was intact and configured as follows:

Switch	Position
Normal/Manual Switch	Manual
Vertical Reference Switch	VG
DF Select Switch	UHF-DF
Selector Switch	SCNS

A.5.12 Marker Beacon Instrument Lights: These light covers were intact, and the select switch was in the low position.

A.5.13 Rudder Trim Indicator: This instrument is powered by the Main DC bus, and would not be powered following the loss of 4 engines and was intact. Its pointer was off scale.

A.5.14 Aileron Trim Indicator: This instrument is powered by the Main DC bus, and would not be powered following the loss of 4 engines and was intact. Its pointer was off scale.

A.5.15 Elevator Trim Indicator: This instrument was missing from the instrument panel and was not recovered.

A.5.16 Electronic Fuel Correction Lights: Three of the four lights were missing and not recovered. The #2 fuel correction light cover was in place.

A.5.17 Beam Coupler Light Cover: This light cover was present.

A.5.18 Autopilot Off Indicator Light Cover: This indicator light cover was missing.

A.5.19 ADF1/ADF2: This instrument will tend to retain its indications upon power loss, but is subject that impact induced changes. The instrument was intact. The Compass Card read 066 degrees, #1 Bearing Pointer indicated 322 degrees while the #2 Bearing Pointer indicated 286 degrees.

A.5.20 Tracker: This instrument's design allows its indications to be easily changed after power loss. The instrument was recovered intact. The compass card indicated 250 degrees and the pointer indicated 185 degrees. Depot analysis revealed the pointer was captured at 180 degrees.

Note: The electro-optical sensor (part of the AAR-47) associated with the ALE-40 system was connected to the pilot's instrument panel by a single wire bundle. That wire was cut and the detector was not further evaluated.

A.6 Copilot's Instrument Panel: The Copilot's Instrument Panel was recovered from the principal Cockpit pile. It was attached to the Engine Instrument Panel.

A.6.1 Cabin Altimeter: This unpowered instrument receives input from the pitot-static system. It is prone to change due to impact or post-crash inputs, unless captured at the time of capture. The indicator was intact and the pointer indicated 42,000 ft. Depot analysis revealed that it was not captured, and the pointer was free to move.

A.6.2 Wing Flap Position Indicator: This instrument is powered by the main DC bus and would not function after the loss of all 4 engines. This gauge was intact and the pointer was off scale.

A.6.3 Landing Gear Control Panel: This panel was intact, and the Landing Gear Handle was down. The Landing gear position indicators were as follows:

Handle	Position
Nose Landing Gear	In Transit
Left Main Landing Gear	In Transit
Right Main Landing Gear	In Transit

A.6.4 Nacelle Overheat Warning Panel: All of the Nacelle Overheat Warning Light Covers were missing except #4, which was intact.

A.6.5 Airspeed Indicator: This unpowered instrument receives input directly from the pitot static system. These indications, if not captured, will be altered by the impact or by post-crash inputs. The instrument was recovered intact, with its glass broken. The Maximum allowable airspeed pointer showed 280 knots and was not captured. The airspeed pointer and the vernier drum were indicating in excess of 400 knots and were not captured.

A.6.6 Attitude Indicator: The Copilots attitude indicator can be powered by the battery through the copilot's inverter and could be available following the loss of four engines. The instrument was intact. It indicated a 90-degree right bank and approximately level pitch attitude. Depot analysis revealed that the indicators were not captured and may have changed following the impact.

A.6.7 Horizontal Situation Indicator: The following indications were visible on deck. The front glass was badly broken and the Compass Card indicated 080 degrees. Analysis by the Depot revealed the following:

Instrument	Indication
Compass Card	082 degrees
Course Arrow	155 degrees
Course Window	155 degrees
Heading Marker	165 degrees
Bearing Pointer	087 degrees
Range Indicator	100 miles (shutter in view)

A.6.8 Altimeter: The altimeter is unpowered and receives direct input from the pitot-static system. If not captured, this instrument is subject to change by impact or by post-impact water pressure changes. The instrument was intact but its front glass was broken. The barometric pressure setting was 29.92. The pointer and drums were not captured by impact. No altitude reading could be obtained.

A.6.9 Vertical Velocity Indicator: This unpowered instrument receives inputs directly from the pitot-static system. This instrument is susceptible to impact induced changes and post impact pressure changes unless captured at impact. The indicator was intact but the front glass was

broken. The pointer was unattached and lying at the bottom of the case. Depot analysis revealed that the rear of the pointer with the counter balance weight was captured by impact in a position that correlates to 800 FPM down.

A.6.10 Radio Magnetic Indicator: This indicator tends to retain the indications prior to loss of electrical power. The indications can change as a result of impact forces. The instrument was intact but the front glass was broken. The Compass Card indicated 040 degrees, and the #1 Bearing pointer was 042 degrees and the #2 Bearing Pointer was indicating 309 degrees.

A.6.11 Clock: The clock was intact and indicated 7:08.

A.6.12 Liquid Oxygen Quantity Indicators: These two indicators were intact and indicated as follows:

Instrument	Indication
Liquid Oxygen Indicator (upper)	23.3 L
Liquid Oxygen Indicator (lower)	21.0 L

A.6.13 Liquid Oxygen Low Quantity Warning Lights: The cover was missing on the upper indicator and present on the lower indicator. The Depot did not analyze these indicators.

A.6.14 Flight Director Mode Selector Panel (SCNS): This panel is used to set the input sources for the HSI and ADI. The copilot's panel was found as follows:

Switch	Position
Normal/Manual Switch	Broken
ADI Normal/Pilot Repeat Switch	Broken
Vertical Reference Switch	Indeterminate
UHF2/DF	Broken
Selector Switch	Rotates freely, position indeterminate

A.6.15 Landing and Taxi Light Panel: This panel was intact and the indicators were in the following positions:

Switch	Position
Landing Light Position Switches	Hold
Left Landing Light Switch	Indeterminate
Right Landing Light Switch	On
Taxi Light Switch	On

A.6.16 Hydraulic Panel: This panel was generally intact. The Depot did not evaluate these instruments.

Utility System	Indication
#1 Hydraulic Pump	Off
#2 Hydraulic Pump	On
Hydraulic Suction Boost Pump Switches	Off
Utility Pressure Gauge	Internal workings were missing
Utility Rudder Boost Pressure Gauge	1050 lbs.
Normal Brake Pressure Indicator Gauge	Missing
Booster System	**Indication**
#3 Hydraulic Pump	Off
#4 Hydraulic Pump	Off
Hydraulic Suction Boost Pump Switches (Booster)	On
Booster Pressure Gauge	Off Scale
Boost Rudder Boost Pressure Gauge	Off Scale
Auxiliary System	**Indication**
Auxiliary System Pressure Gauge	Pointer Missing
Auxiliary Pump Switch	Off
Anti Skid Selector Switch	Red Guarded Switch Cover –closed
Emergency Brake Pressure Indicator Gauge	Missing
Other	
Hydraulic Low Pressure Warning Lights	Present
Brake Selector Switch	Normal

A.6.17 Copilots ADI Repeat Caution Light: This light cover was in place.

A.6.18 Selected Nav System Off Caution Light: The cover of this caution light was missing.

A.7 Copilot's Side Shelf: The Copilot's Side Shelf was recorded photographically and on videotape but not recovered. It is briefly described here because crew actions related to four-engine roll back procedures involve the propeller control switches on this panel. All visible switch/knob positions are recorded.

A.7.1 Lighting Controls:

Switch/Knob	Indication
Copilot's Instrument Light Rheostat Knob	Intact, pointed at 2 o'clock position
Copilot's Flood Light Rheostat Knob	Knob missing
Overhead Panel Light Rheostat Knob	Intact, pointed 4 o'clock
Overhead Panel Flood Light Rheostat Knob	Knob missing

A.7.2 Propeller Panel:

Switch	Indication	
Propeller Valve and NTS Check Lights	All four are present	
Propeller Valve and NTS Check Switch	NTS Position	
Propeller Feather Override Switches	Intact, Position Indeterminate	
Master Trim Knob	Intact, 2 o'clock	
Propeller Governor Control Switches	**Red Guard**	**Switch Position**
#1	Open	Normal
#2	Closed	Normal
#3	Open	Mechanical
#4	Broken off at base	Mechanical

A.7.3 Copilot's Oxygen Regulator:

Switch	Indication
On/Off Lever	Off
Normal/100 %	100%
Emergency/Normal/Test Mask	Indeterminate

A.8 Navigator's Panel (Partial): The Navigator's control panel was recovered from the main cockpit wreckage area. It was removed by Deep Drone, by the standard technique and brought to the surface in a basket. The following indications were recorded:

Instrument	Indication
Radio Selector Switch	FM-1
True Airspeed Indicator	Needle missing
Altimeter	-2400 ft
Barometric Pressure setting	29.92
Free Air Temperature	Below –70
Radar Altimeter	
Variable Altitude Limit Index	240 feet
#1 Pointer Select Switch	Tracker
Course Indicator	Needle and instrument face missing
Forward Bearing Distance Heading Indicator (BDHI)	Heading 080
#1 Bearing Pointer (VOR 1)	120
#2 Bearing Pointer (TAC 1)	095
Aft BDHI	Heading 080 (with off flag)
#1Bearing Pointer (VOR2)	215
#2 Bearing Pointer (TAC 2)	215
Light Switch	Full Bright
Clock	0700

A.9 Direction Finder Set. The RD288/ARD-17 Direction Finder Set was recovered only because of its close proximity to the recovery basket. This set has no bearing on the mishap.

A.10 Pressurization Panel: The pressurization panel was removed from the main cockpit wreckage area.

The position of the switches upon recovery aboard ship were recorded as follows:

- Cabin Altitude knob – set to ~1900 feet
- Rate knob – set to approximately the 2 o'clock position. This is approximately half way between the mid- point of the travel of the knob (approximately 900 FPM) and the max position (1600-2900 FPM).
- Cabin Differential Pressure Gage – not present
- Cabin VVI - ~5600 FPM rate of descent.
- Emergency Depressurization Switch – The red guard was missing. The switch appeared to the in the NORMAL position.
- Manual Pressure Control Switch – The switch body was present but the switch toggle was missing. This switch is spring loaded to the center position and must be held to either the INCREASE or DECREASE pressure position. Unless the flight engineer was physically holding the switch to either the INCREASE or DECREASE position at the time of impact the switch would have been in the center position.
- Under Floor Heating Switch – switch was positioned to OFF.
- Cargo Compartment Air Conditioning Switch – switch was missing.
- Flight Deck Air Conditioning Switch – The toggle of the switch was bent to approximately the 2 o'clock position. The actual position of the switch could not be determined.
- Air Conditioner Master Switch – The switch was positioned to the AIR COND NO PRESS position.
- Cargo Compartment Temperature Control – switch position could not be determined.
- Flight Deck Temperature Control – switch was positioned to AUTO.
- Cargo Compartment Temperature Rheostat – Full Warm.
- Flight Deck Temperature Rheostat – 3 o'clock position.

A.11 GTC/Anti-Icing/Bleed Air Panel. The GTC/Anti-Icing/Bleed Air panel was removed from the main cockpit wreckage area. These switch positions cannot be considered reliable due to crew actions after electrical power loss, impact forces, or recovery efforts.

A.11.1 GTC Switches. The position of the switches relative to the GTC upon recovery aboard ship were recorded as follows:

- GTC Door Switch – The switch was pulled through the panel. The position of the switch could not be determined.
- GTC Control Switch – The switch was positioned between OFF and RUN.
- Door Open Light – Light was present.

- Start Light – Light was present but the lens was broken/missing.
- On Speed Light – Body of the switch was present but the light was missing.
- GTC Bleed Air Valve – The switch was in the CLOSED position
- ATM Switch – The switch was in the CLOSED position

A.11.2 Anti-Icing Switches. The position of the switches relative to the Anti-Icing system upon recovery aboard ship were recorded as follows:

- Center NESA – The switch was present but the toggle was broken. The position of the switch could not be determined.
- Side and Lower NESA – The switch was positioned to OFF.
- The COLD START switches for both the Center and Side and Lower NESA systems were present. These switches are spring-loaded push buttons.
- Nacelle Preheat switches – All four switch bodies were present but all the toggles were broken off.
- Propeller and Engine Anti-Icing Master switch – The switch appeared to be in the AUTO position with the switch bent upward.
- Pilot's Pitot Heat – The switch was ON
- Copilot's Pitot Heat – The switch was OFF
- Engine Inlet Air Duct Anti-Icing switches – All four switches were in the OFF position.
- Propeller Ice Control switches – The #1 switch was in the OFF position. The #2, #3, and #4 switch positions could not be undetermined due to the switch bodies being missing.
- Spinner Anti-Icing meter – Meter was missing the glass. The amp meter indicated approximately 20 amps.
- Spinner De-Icing meter – Meter was missing the glass. The amp meter indicated approximately 45 amps.
- Blade De-Icing meter – Meter was missing the glass. The amp meter indicated in excess of 100 amps.
- Leading Edge Temperature Indicators – The Left Outer Wing temperature indicator indicated at the lower end of the Inoperative range. The Right Inboard Wing temperature indicator indicated on the line separating the Inoperative and the Normal range. The other four leading edge temperature indicators were missing from the panel.

A.11.3 Bleed Air Switches. The position of the switches relative to the Bleed Air section upon recovery aboard ship were recorded as follows:

- Left Isolation Valve – The red guard and switch were missing.
- Right Isolation Valve – The red guard was missing. The switch appeared to be in the NORMAL position.
- #2 Bleed Air Valve - OPEN
- #3 Bleed Air Valve - CLOSED
- #1 Bleed Air Valve - CLOSED
- #4 Bleed Air Valve – CLOSED

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A.12 Electrical Panel. The Electrical panel was removed from the main cockpit wreckage area. These switch positions cannot be considered reliable due to crew actions after electrical power loss, impact forces, or recovery efforts.

A.12.1 Light Control Switches. The position of the switches relative to the lighting panel upon recovery aboard ship were recorded as follows:

- Strobe, Top – switch was in the WHITE position.
- Strobe, Bot – switch was in the WHITE position.
- Navigation Light Flash/Steady switch – switch was in the STEADY position.
- Navigation Light Wing switch – switch was in the BRIGHT position.
- Navigation Light Tail switch – switch was in the OFF position.
- Leading Edge lights switch – back of the switch was missing, switch position could not be determined.
- Formation Light Selector switch – switch was in the BOTH position.
- Fuselage Light switch – switch was in the BRIGHT position.
- Strobe Inhibit switch – switch was in the LO COV position.
- Formation Light rheostat – rheostat was in the full bright position.
- The Bus Off Indicator lights were all present with the exception of the Main AC OFF light which was missing.

A.12.2 Electrical Panel Switches. The position of the switches relative to the electrical panel upon recovery aboard ship were recorded as follows:

- Generator Disconnect Fired Lights – #1 and #3 light lens were present. The #2 and #4 lens were missing.
- Generator Out Lights – All four engine generator out light and the ATM generator out light lens covers were missing.
- Generator Disconnect Switches – The #1 generator disconnect red guard was broken but the switch appeared to be in the OFF position. The #2, #3, and #4 switches were found with the red guards closed.
- Generator Switches – The #1 and #4 generator switches were in the ON position. The #2, #3 and the ATM generator switches were in the OFF position.
- AC Loadmeters – The AC loadmeters were all present. The glass covers for the #1, #2, #4, and the ATM were broken. The glass for the #3 loadmeter was intact.
- Generator Disconnect Test Switch – The generator disconnect test switch was present and found in the OFF position.
- External AC Power Switch – The switch was in the OFF position.
- AC Instrument and Engine Fuel Control Inverter – The switch appeared to be in an intermediate position between the AC and DC position. The placard panel was broken in the area of this switch.
- Copilot's AC Instruments Inverter – The switch was in the DC position.

- DC Transformer Rectifiers meters – All the DC loadmeters were present. The reading on all DC loadmeters was less than 0. The glass was broke on the #1 and #2 ESS meters while the glass was intact on the #1 and #2 MAIN meters.
- DC Power Switch – The switch control knob was missing. Switch position is unknown.
- Bus Tie Switch – The red guard on the bus tie switch was closed with the switch in the NORMAL position.
- AC Frequency Meter - The glass was missing from the meter.
- AC Voltmeter – The AC voltmeter was intact with the meter indicating between 0 and 50 volts.
- Phase Selector Switch – The phase selector switch was positioned to Phase A.
- Voltmeter Selector Switch – The selector switch was positioned to the #1 generator.
- DC Voltmeter Selector Switch – Positioned in an intermediate position near the BATTERY position.
- DC Voltmeter – The DC voltmeter was missing.
- INS Battery Charge switch – The INS battery charge switch was positioned with the red guard up. The switch body was missing so the switch position could not be determined.

A.13 Circuit Breaker Panels-Main AC BUS/Essential DC BUS/Radio Circuits: This set of two panels was recovered incidentally while recovering the pilot's instrument panel. Many of the circuit breakers were pulled from the panel, while several others are bent in place. The extensive damage observed on the panel convinced the on board BAR team members that the circuit breaker positions were not reliable, and therefore the positions of the breakers were not recorded.

A.14 Emergency Water Jug. One emergency water jug was recovered on 27 Jun 98. The water jug was inadvertently recovered during the rigging of lift slings around the LH Benson tank. When the ROV, rigged with an extension and sling, was manipulated between the Benson tank cradle and the attached cargo floor the extension rod speared the water jug.

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Appendix B

Summary of Reports on Analyses of Parts Recovered during the Salvage Operation

This appendix lists and summarizes the reports on those items recovered during this salvage operation which were sent to Air Force depots or laboratories for analysis.

Part Analyzed	Analyzed by	Report Status
#1, 2, LH & RH Aux, LH & RH fuselage tank foam assessment	WL/MLSA and ASC/ENF Aeronautical Systems Center Wright Patterson Air Force Base, OH 45433-7718	Final dated 5 Aug 98

Summary of Report: The foam from the tanks was tested using the methods and procedures outlined in MIL-F-87620. The assessment concluded that the ESM foam was in good condition at the time of the mishap. The results do not indicate the ESM foam was a contributing factor in the mishap.

Part Analyzed	Analyzed by	Report Status
Fuselage (Benson) tank fuel pumps	Report No. AFRL/MLSA 98-126 Air Force Research Laboratory Systems Support Division, AFRL/MLSA 2179 12th Street Wright Patterson Air Force Base, OH 45433-7718	Final dated 31 Jul 98

Summary of Report: The fuselage tank pumps (four total) were analyzed by AFRL/MLSA. The submitted pumps were analyzed using nondestructive inspection, electrical conductivity measurement, disassembly, visual inspection, reassembly, and dry-run operation. Each pump was dry-run for at least one minute. No anomalies were identified to indicate the pumps were not operational at the time of power loss.

Part Analyzed	Analyzed by	Report Status
Fuselage (Benson) tank fuel pumps (measurements)	Lab Control No. 98VA-ENGR-118 SA-ALC/LDPF San Antonio Air Logistics Center (AFMC) Kelly Air Force Base, TX 78241-6449	Final dated 3 Aug 98

Summary of Report: The fuselage tank pumps (four total) were evaluated by SA-ALC/LDPF. Specific components of each pump were dimensionally inspected for conformance to T.O. 6J10-3-102-3 (Atch 1). After the dimensional inspection was completed, all four pumps were reassembled and functionally tested on the test stand. All four pumps passed required testing by the technical order.

Part Analyzed	Analyzed by	Report Status
Fuel Crossfeed Primer Valve	SA-ALC/LDPF San Antonio Air Logistics Center 580 Perrin Rd. Kelly Air Force Base, TX	Final dated 31 Jul 98

78241-6449

Summary of Report: The fuel crossfeed primer valve was evaluated by SA-ALC/LDPF. The actuator motor housing was oriented 180° from its normal position causing the "open" and "closed" indicators on the motor to disagree with the "open" and "closed" indicators on the housing. The orientation of the motor housing did not affect the operation of the actuator on the valve. The valve functioned properly in that it opened when 28VDC was applied to pin "A" and closed when 28VDC was applied to pin "B," IAW T.O. 8D1-14-52-373. Neither the actuator nor motor technical order specify an orientation for the motor housing.

#2 main tank vent line	Report No. AFRL/MLSA 98-132 Materials & Manufacturing Directorate Air Force Research Laboratory Systems Support Division, AFRL/MLSA 2179 12th Street Wright-Patterson Air Force Base, OH 45433-7718	Final dated 5 Aug 98

Summary of Report: AFRL/MLSA was tasked to determine if the Wiggins-type coupling was mechanically engaged and if the safety wire was intact at the time of impact. The threads on both sections of the coupling were examined and no damage consistent with forced separation was found. Cuts using common wire cutting tools were compared to the submitted safety wire. Laboratory cuts exhibited features similar to the submitted safety wire. It was concluded that the coupling was not mechanically engaged and the safety wire was not attached at the time of impact.

#1 and 2 main's, LH and RH Aux tank boost pumps, and #4 main dump pump	Materials and Manufacturing Directorate Air Force Research Laboratory Systems Support Division, AFRL/MLSA 2179 12th Street Wright-Patterson Air Force Base, OH 45433-7718	Final dated 5 Aug 98

Summary of Report: The subject pumps (five total) were analyzed by AFRL/MLSA. The submitted pumps were analyzed using nondestructive inspection, electrical conductivity measurement, disassembly, visual inspection, reassembly, and dry-run operation. Each pump was dry-run for at least one minute. No anomalies were identified to indicate the pumps were not operational at the time of power loss.

Flight deck instruments and Fuselage (Benson) tank fuel gauges	OC-ALC/LIINT Tinker AFB, OK 73145-3029	Final dated 29 Jul 98

Summary of Report: These instruments and gauges were analyzed by OC-ALC/LIINT. All of the instruments sustained impact and salt-water damage. Fuel quantity

indicators tend to retain the indication existing upon loss of electrical signal. The pointer positioning mechanisms for all recovered gauges were intact. They were in positions which correlated to the following readings:

#1 Main Tank	- Approximately 7,000 lbs.
LH Aux Tank	- Approximately 4,000 lbs.
LH Fuselage Tank (fuel panel gauge)	- Slightly less than 600 lbs.
LH Fuselage Tank (tank gauge)	- Slightly less than 600 lbs.
RH Fuselage Tank (fuel panel gauge)	- Approximately 300 lbs.
RH Fuselage Tank (tank gauge)	- Approximately 300 lbs.

Nothing was noted to indicate instrument or instrument system failure prior to impact or loss of input signal.

#1, 2,and 3 engines and components	SA-ALC/LPEBT San Antonio, TX 78241-6449	Final dated 28 Jul 98

Summary of Report: The three recovered engines and components were examined by SA-ALC/LPEBT with an NTSB representative present. There were no signs of rotation damage in either the compressor inlet or compressor bleed valve ports in any of the engines. The TD valves on all three engines were in a slight put position.

Fuselage (Benson) tank pump relays	AFRL/ MLSA Air Force Research Laboratory 2179 12th Street Wright-Patterson AFB, OH 45433-7718	Final dated 6 Aug 98

Summary of Report: The fuselage tank pump control relays were inspected by AFRL/MLSA. All were examined for wire condition and coil resistance and disassembled for visual signs of damage. There was no evidence of contact welding or other pre-mishap anomalies in any of the components that would have affected their operation.

Fuselage (Benson) tank quantity probes	AFRL/MLSA 2179 12th Street Wright-Patterson AFB, OH 45433-7718	Final dated 7 Aug 98

Summary of Report: Both the LH and RH fuselage tank fuel probes were analyzed by AFRL/MLSA. Visual and optical inspections were conducted but electrical testing was not possible due to impact damage. There were no signs of pre-mishap anomalies noted.

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Appendix C

Schedule of Key Events during Salvage Operation

Date	Event/Activity
27 May 98	M/V Auriga, based in Seattle, WA, commenced preparation for wing search mission
29 May 98	M/V Auriga underway to wing search area
01 Jun 98	M/V Auriga arrived onsite at wing search area and commenced operations
10 Jun 98	M/V Auriga moves to Eureka due to bad weather
15 Jun 98	M/V Independence arrives Oakland Naval Supply Center (NSC) and begins loading ROV and associated equipment
16 Jun 98	Pierside press conference conducted by Maj Gen Bobby O. Floyd at Oakland NSC
17 Jun 98	Five C-130 BAR members embark M/V Independence
	M/V Independence departs Oakland NSC at 1330 local for target #l in the wing search area
	M/V Auriga departs Eureka for wing search area
18 Jun 98	Shore Team (three individuals) relocates to Travis AFB to coordinate support activities for C-130 Salvage Operations
19 Jun 98	M/V Auriga and M/V Independence return to port (Eureka) at 0830 due to bad weather and mechanical problems with the Remotely Operated Vehicle – Deep Drone
20 Jun 98	Shore Team establishes operations center in Eureka
	M/V Auriga and M/V Independence depart for wing search area at 2200L
21 Jun 98	M/V Independence repositions to site of King 56 main debris field and begins initial dive of Deep Drone
22 Jun 98	Left fuselage (Benson) tank recovered
23 Jun 98	Right fuselage (Benson) tank recovered

	Rigged first engine (#3) for recovery
24 Jun 98	Recovered #3 engine
	Rigged second engine (#2) for recovery
	Mechanical problems with Deep Drone—manipulator arm, preventing recovery of second engine
	Repositioned Deep Drone to flight deck area
	Deep Drone recovered when thruster arm malfunctioned
25 Jun 98	Deep Drone repaired and returned to flight deck area
	Placed numerous overhead panels from flight deck area in prepositioned basket for eventual recovery
	Deep Drone recovered for repair of thruster (jammed with debris)
26 Jun 98	Recovered basket containing numerous overhead panels from flight deck area
	Contacted personnel at Federal Archives in San Bruno, CA who faxed copies of USCGC Buttonwood's log (entries 22-28 Nov 96) to Shore Team in Eureka
	Last known position of wing, as identified in USCGC Buttonwood's log, passed to BAR members aboard M/V Independence
	Recovered second engine (#2)
27 Jun 98	M/V Independence returned to Eureka at 1600L due to bad weather and was met by local media who videotaped recovered wreckage
	Decision made to expand wing search area based upon information obtained from USCGC Buttonwood's log entries for 22-28 Nov 96 to include last known position
28 Jun 98	M/V Independence delays scheduled departure due to malfunctioning hoist mechanism for Deep Drone
29 Jun 98	M/V Independence departs Eurkea at 1145L
	M/V Independence returns to Eureka because USN Supervisor of Salvage

	representative has family emergency
	M/V Independence departs at 1900L
	M/V Auriga locates wing using side scanning sonar
30 Jun 98	M/V Auriga returns to Eureka at 0700L and offloads US Navy equipment used to search for wing section
	M/V Independence uses Deep Drone to visually identify wing section
	Due to logistic problems, decision is made to bring wing section back to Eureka and not to Oakland as originally planned
	M/V Auriga departs Eurkea at 1900L – mission complete
	Rigged wing section for recovery
01 Jul 98	Specialist from Oklahoma City Air logistics Center (OC-ALC) arrived to analyze recovered instruments
	Unsuccessfully attempted to recover wing section—broke free from cables during efforts to bring it aboard the ship
	M/V Independence delayed additional efforts to recover wing due to bad weather and repositioned to main debris site
	Trucked two engines, two fuel probes, four fuel pumps, and foam samples from both fuselage tanks to Travis AFB for eventual transport to San Antonio ALC and Wright-Patterson AFB via C-130
02 Jul 98	Photographer and videographer from Vandenberg AFB flew mission with local US Coast Guard helicopter unit to video and photograph M/V Independence conducting operations at sea
	C-130 with recovered King 56 components departs Travis AFB for SA-ALC, then Wright-Patterson AFB, OH
	Trucked both Benson tanks and crate full of miscellaneous components to Travis AFB for storage in hangar 810
	M/V Independence returned to Eureka at 1530L to wait out bad weather and ordered additional equipment for use in securing wing section during future recovery attempts

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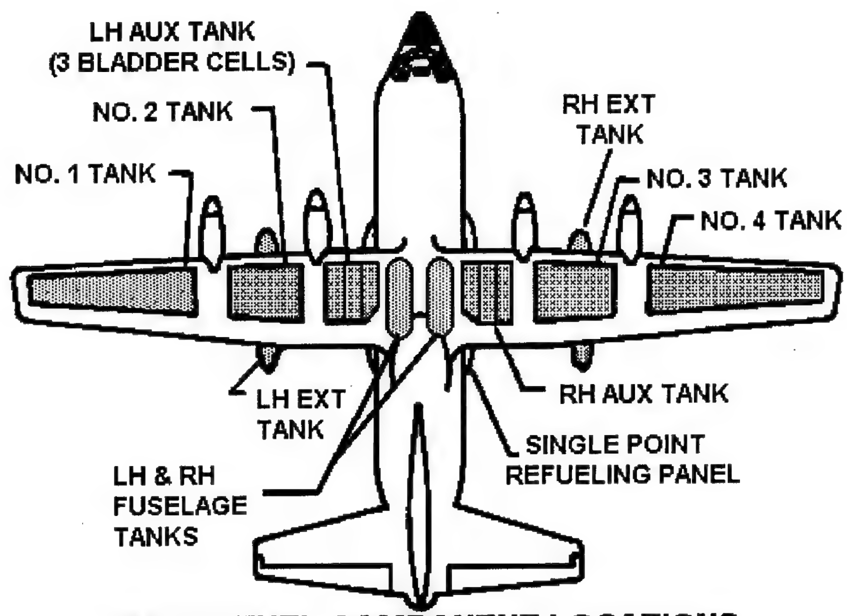
03 Jul 98	OC-ALC representative completed his analysis of recovered instruments and turned in his report
04 Jul 98	Equipment ordered for use in recovering wing section arrived at 1830L
	M/V Independence departs for wing search area at 2008L
05 Jul 98	Rigged wing section with recently purchased heavy chain
06 Jul 98	Continued rigging wing section with recently purchased heavy chain
	Deep Drone eventually recovered due to bad weather
	Distributed video coverage of M/V Independence conducting operations at sea to local and Portland area news stations
07 Jul 98	M/V Independence moved to main debris field
	M/V Independence returns to Eureka at 2230L to offload one ship's crewmember with scheduled leave
	M/V Independence departs Eureka at midnight
08 Jul 98	Deep Drone operations commence on main debris field
09 Jul 98	One human remain disturbed slightly in order to move right wheel well section in an attempt to locate the single point refueling (SPR) panel
	Rigged and recovered the last (#1) engine for recovery
10 Jul 98	Recovered wing section and additional dive made to ascertain if portions of the wing were lost during its retrieval
	M/V Independence moved to main debris field
11 Jul 98	Basket recovered with miscellaneous components
12 Jul 98	Deep Drone is recovered for the final time after making dive #30
	The photographer and videographer from Vandenberg AFB fly mission aboard USCGC helicopter to cover arrival of M/V Independence with wing section and other recovered wreckage
	M/V Independence arrives Eureka at 1815L with Maj Gen Floyd in attendance

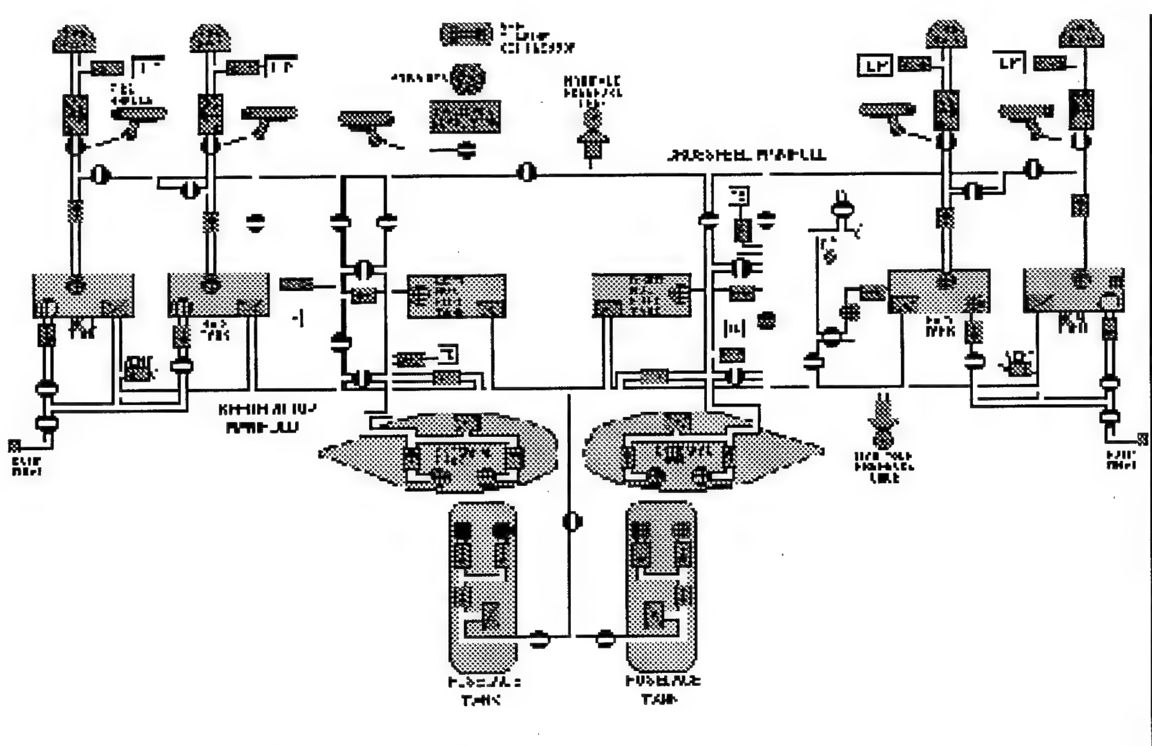
13 Jul 98	Press conference conducted by Maj Gen Floyd with Eureka mayor and local media in attendance
	Wing section, engine, and other recovered King 56 components removed from ship
	M/V Independence departs Eureka at 2200L
14 Jul 98	Called Oakland NSC POC and notified him of M/V Independence's expected arrival for outfitting of USN equipment used for salvage operations
	Combat Logistics Support Squadron (CLSS) personnel begin trimming down wing section to allow ground transport via tractor-trailer truck to Travis AFB
15 Jul 98	One engine, four bags of foam, five fuel pumps, fuel valves, and crate containing miscellaneous King 56 components trucked to Travis AFB
16 Jul 98	C-130 with engine, foam, pumps, and valves departs Travis AFB for SA-ALC and Wright-Patterson AFB
	Wing section trucked to Travis AFB for storage in hangar 810
17 Jul 98	Shore Team completed shutdown of support activities in Eureka
18 Jul 98	Remaining Shore Team and additional BAR member travel via ground transportation to Travis AFB to return equipment and prepare for removal of foam from both Benson tanks and remaining fuel tanks in wing section.
20 Jul 98	Both Benson tanks and the wing section are moved from hangar 810 to hangar 808 to begin removal of foam from all fuel tanks
	Travis AFB Fire Department personnel cut one end off both Benson tanks to facilitate removal of foam
	Fuel cell personnel from Moffett Federal Airfield (129 RQW) begin removal of fuel foam from Benson Tanks and #2 Main tank in wing section
21 Jul 98	Four fuel probes and one dump pump removed from #2 Main tank
	Foam removal continues from both Benson tanks and the two auxiliary fuel tanks in wing section

22 Jul 98	Foam completely removed from both auxiliary tanks and the left and right hand Benson tanks
	Both Benson tanks, both auxiliary tanks, and the #2 main tank are inspected for abnormalities
23 Jul 98	Removed foam that is dry is bagged and returned to storage in hangar 810
24 Jul 98	Wing section and Benson tanks returned to hangar 810

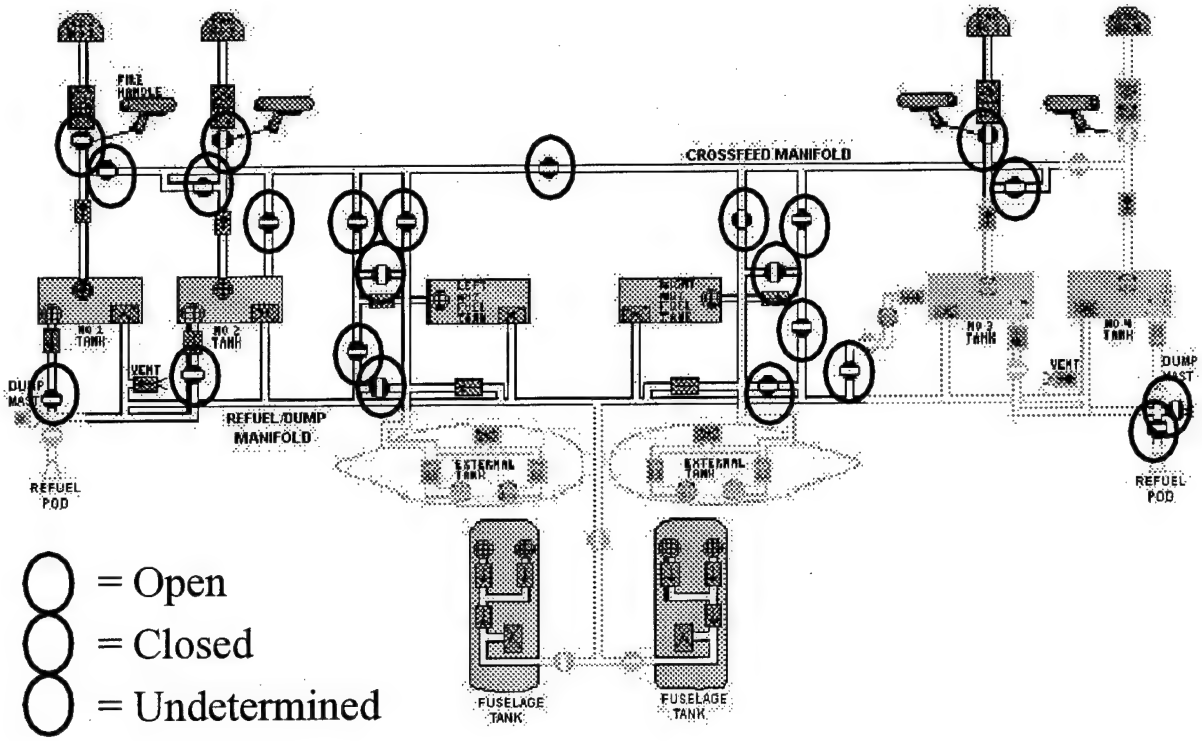
Diagrams of HC-130 Fuel System



MAJOR FUEL COMPONENT LOCATIONS



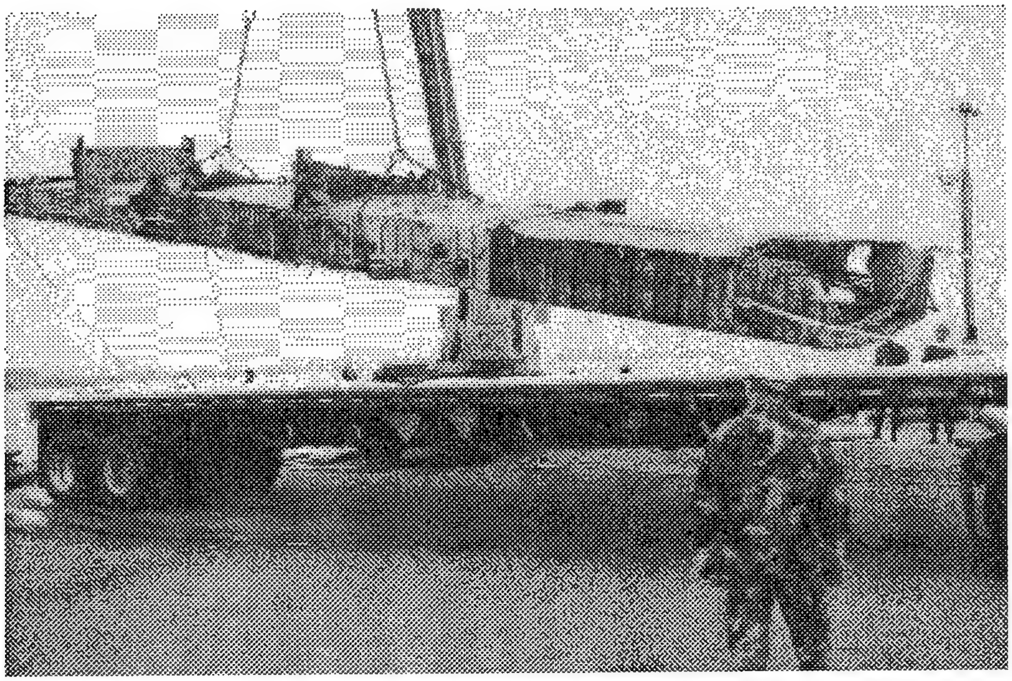
Basic Components of the HC-130 Fuel System



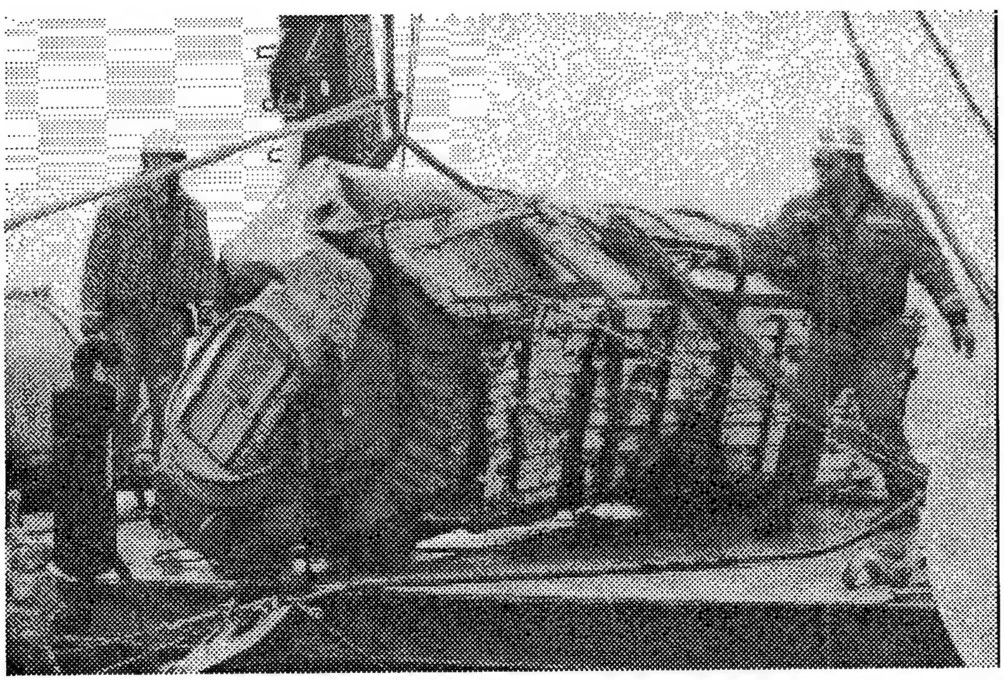
Valve Positions from Recovered Wreckage

Appendix E

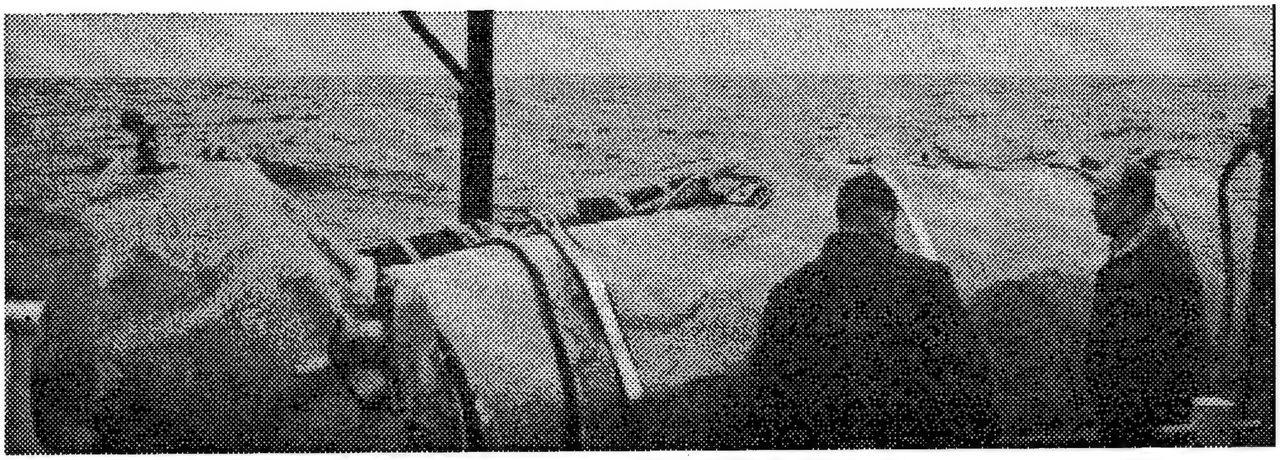
Photos of Selected Wreckage



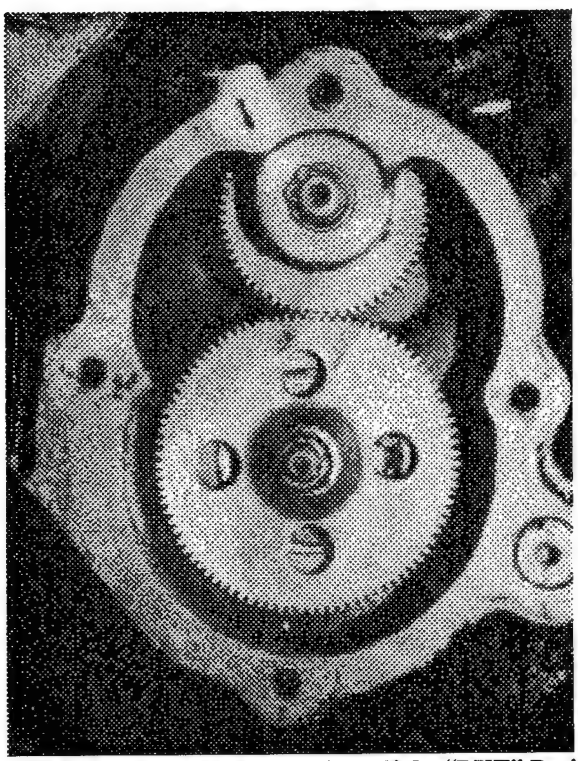
Center Wing Section Being Loaded for Transport



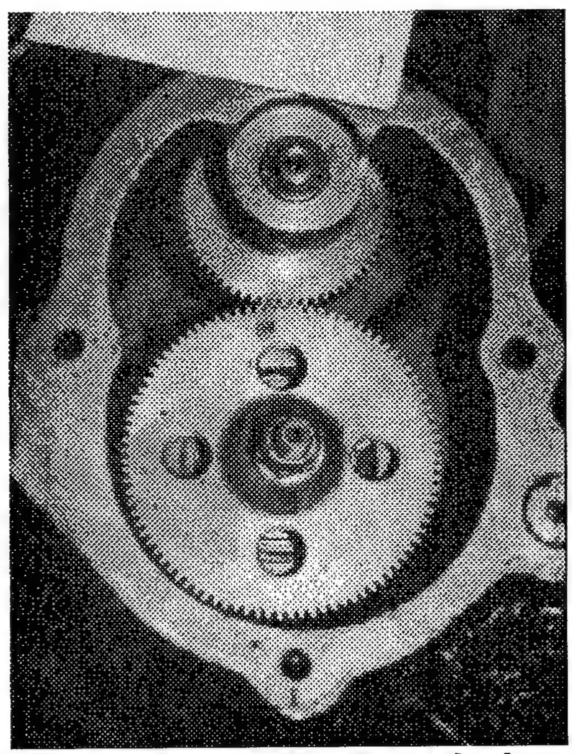
RT Fuselage Tank on Deck of M/V Independence



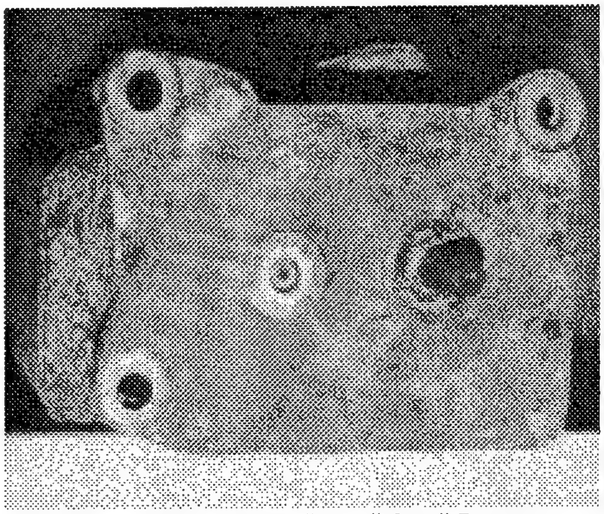
LT Fuselage Tank on Deck of M/V Independence

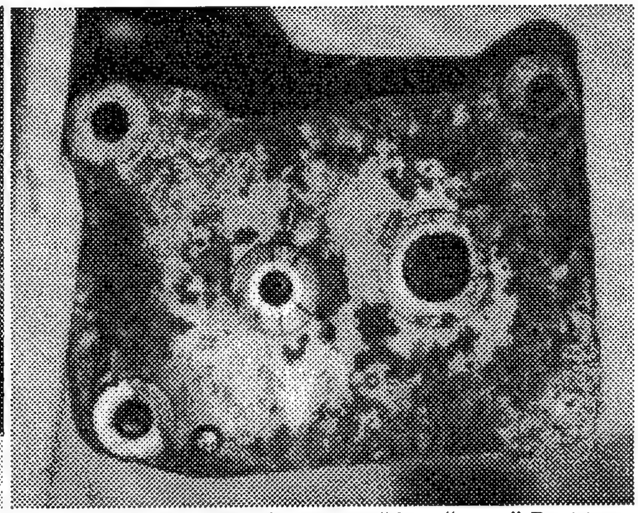


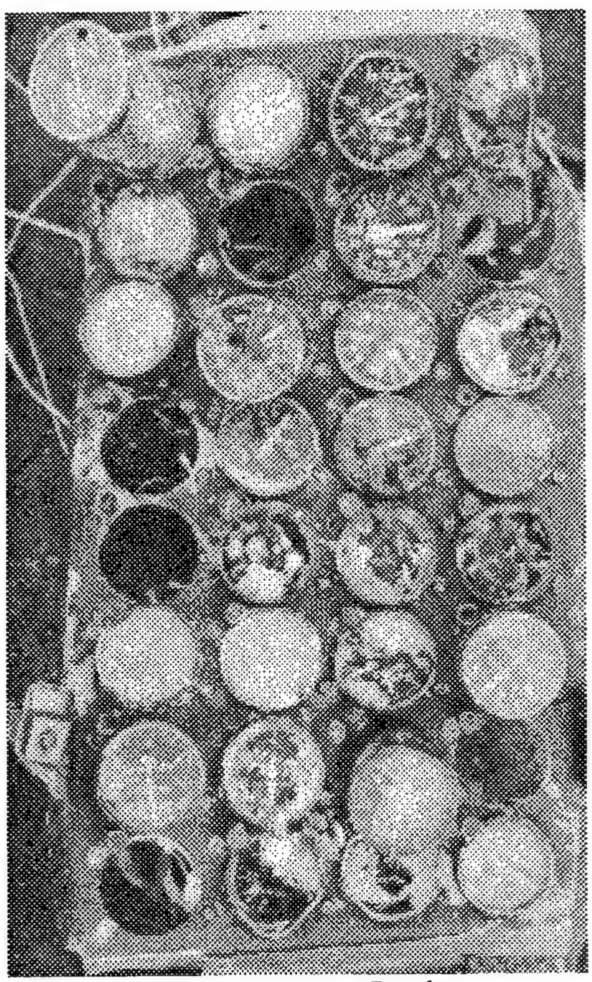
TD Valve from #1 Engine, in a slight "PUT" Position

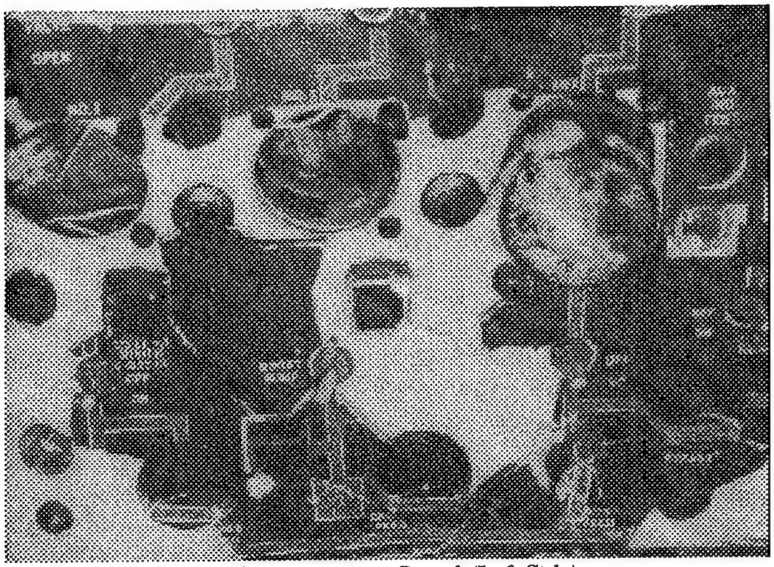


TD Valve #1 with the Motor Removed and now in NULL

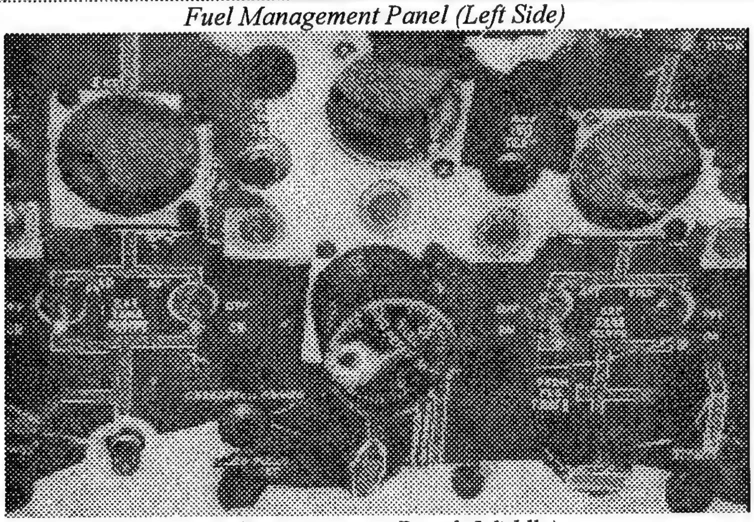

Fuel Shutoff Valve Motor #1 in "close" Position


Fuel Shutoff Valve Motor #3 in "open" Position

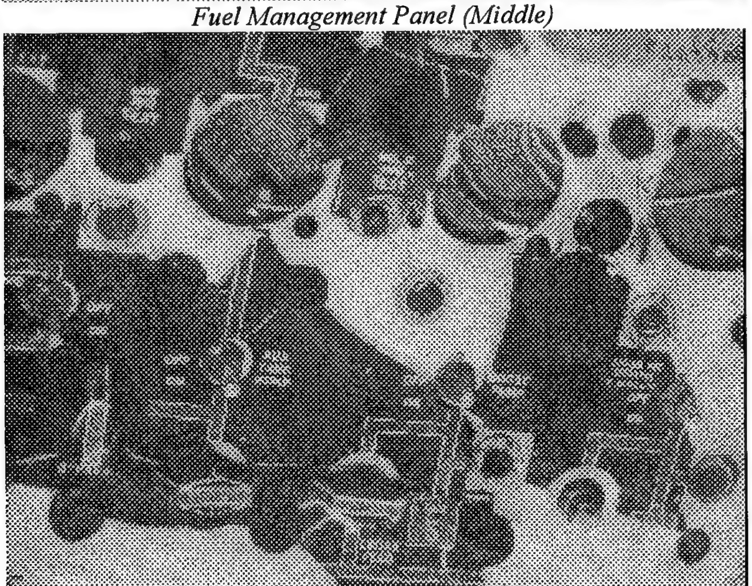

Engine Instrument Panel



Fuel Management Panel (Left Side)



Fuel Management Panel (Middle)



Fuel Management Panel (Right Side)

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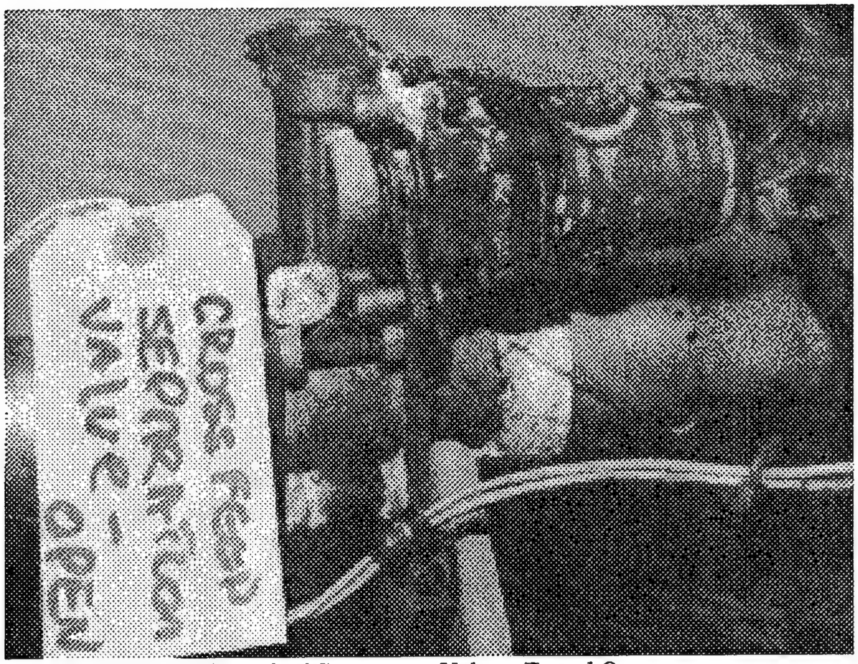
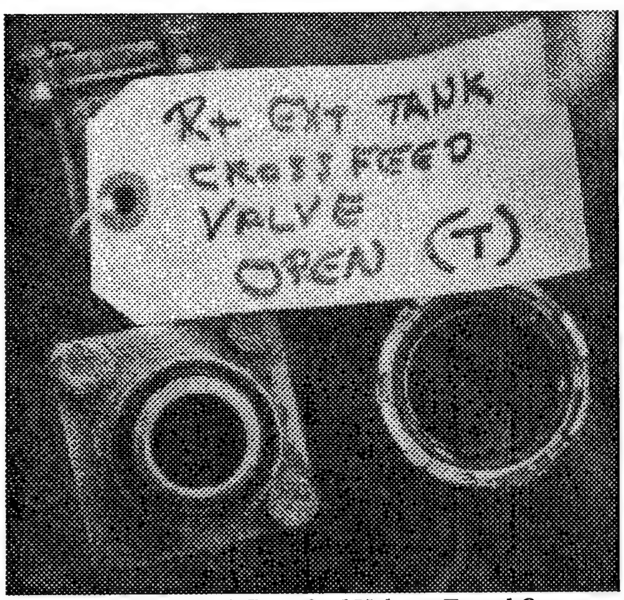
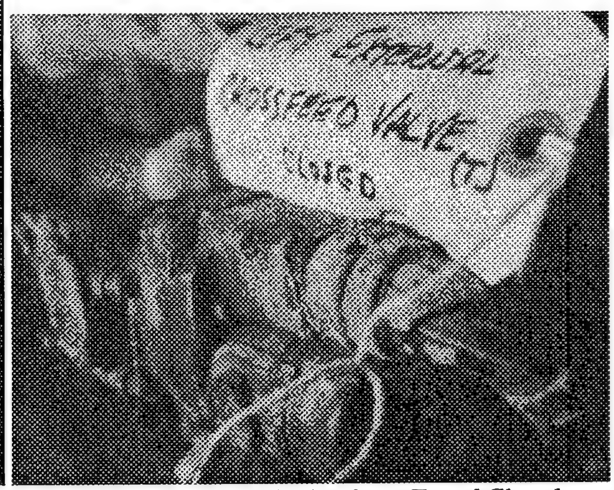


Crossfeed Separation Valve - Found Open



Right External Crossfeed Valve – Found Open



Left External Crossfeed Valve – Found Closed

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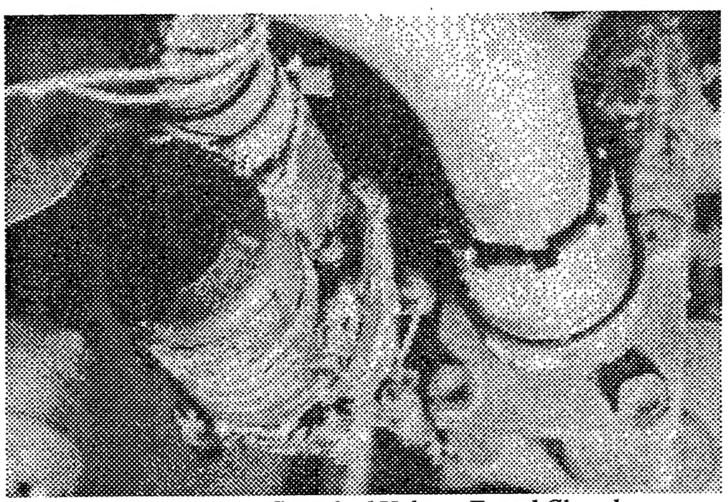
Right Auxiliary Crossfeed Valve – Found Closed

#3 Crossfeed Valve – Found Open



Left Auxiliary Crossfeed Valve – Found Closed

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Appendix F

Records Review Summary

SUMMARY OF 64-14856's RECENT MAINTENANCE HISTORY RELATIVE TO FUEL WRITE-UPS							
INFO SOURCE		781 DISC	EVENT-ID	WRITE-UPS FOR "ON-EQUIPMENT" PROBLEMS	781 CORR	CAMS CORR	CORRECTIVE ACTION
781s	CAMS	DATE		(preference is given to actual wordings in 781s vs. "synopses" in CAMS)	DATE	DATE	(preference is given to actual wordings in 781s vs. "synopses" in CAMS)
X		20-Nov-95	953240075	Awaiting maintenance, RT Aux tank leaking (words from 781's NOTE page)	OPEN		
	X	18-Dec-95	95352B004	LT & RT Benson tanks disconnected for ISO		16-Jul-96	Installed the RT Benson tank (no words on LT Benson tank installation)
	X	28-Feb-96	960590028	Cann A/R drouge for A/C 0970		11-Jun-96	Install after Cann; See JCN 961430051001
	X	7-Mar-96	960670012	Cann A/R reel for A/C 4860		10-Jul-96	Install after Cann; See JCN 960445103001
	X	7-Mar-96	960670093	Assist hyd with A/R reel removal		26-Jun-96	Replaced hose IAW 6A8-3-1, complied with IPI inspection IAW 1C-130(H)H-2-14, and 6A8-3-1
	X	3-Jul-96	961855101	RT aft surge suppressor will not hold pre-charge		16-Jul-96	Remove and replace surge suppress, leak check good IPI due during installation IPI C/W 6A8-3-1 J Phillips 00245
X	X	2-Aug-96	962155111	LH Benson tank refuel valve neck below b-nut bent	3-Aug-96	11-Sep-96	Replaced tank; remove and replace fitting; resealed fitting and completed paper work for in shop work
X	X	3-Aug-96	962165105	LH Benson tank F/Q is dead (on tank) -- stuck at 2000 lbs	can't read	7-Aug-96	Replaced LT Benson tank F/Q indicator; ops ck sat IAW 1C-130(H)H-2-6 Replaced F/Q indicator with ind from tank in corrosion hngr op ck sat; ind on order will go into tank in hngr when rcvd
X	X	5-Aug-96	962185101	Fuel leak #2 Eng	5-Aug-96	5-Aug-96	Tightened B-nut on fuel drain line from TD valve IAW 1C-130(H)H-2-2
X	X	5-Aug-96	962155111	LH Benson tank requires leak check and ops check	5-Aug-96	**11-Sep-96**	Leak chk refuel lines and vent lines ops ck boost pumps and refuel level valve IAW TO 1C-130(H)H-2-6
X		5-Aug-96	962190005	One time inspection of exposed fuel quan shielding data code B608006	5-Aug-96		C/W inspection of F/Q shielding. Installed protective tape as required IAW data code B608006
X	X	20-Sep-96	962727231	RT A/R hose removed due to damage. Hyd line also damaged (reel hap) Hose removed and fuel lines capped. Tunnel nut was missing. C/Bs pulled	10-Oct-96	28-Oct-96	Replaced RT A/R hose and hyd lines. Performed leak check IAW 1C-130(H)H-2-14 check good, inflight op's ck due

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X		28-Sep-96	962725107	LH ext tank F/Q indicator went off scale low when turning the fwd pump on	OPEN		
X	X	3-Oct-96	962780032	RT Aux tank C/B has wrong amp installed	can't read	6-Oct-96	7.5 amp C/B ok IAW 1C-130(H)H-2-8 per elen shop
X	X	9-Oct-96	962835103	LT Benson fuel tank quantity guage on the tank rotating/spinning	30-Oct-96	30-Oct-96	Adjusted empty and full pots on indicator sys op chked sat IAW TO 1C-130(H)H-2-6
X	X	15-Oct-96	962895101	Fuel leak LT outer wing stat "0" LT	15-Oct-96	17-Oct-96	Inspect flapwell, boost pump plate and dry bay. Screw on splice panel leaking; installed proper length screw, leak check good IAW 1-1-3
X	X	16-Oct-96	962905101	Fuel leak LT Benson tank aft valve	can't read	16-Oct-96	Tighten jam nut on aft drain valve leak check for 10 min no leak noted IAW TO 1-1-3
X	X	16-Oct-96	962905103	A/R fuel press indicating sys gauges inop Inflight refueling reel fuse blown. Changed fuse, blew again	16-Oct-96	16-Oct-96	Replace fuse. Ops check sat IAW TO 1H-130(H)H-2-6
X	X	16-Oct-96	962905169	Fuse blown for A/R hose and A/R manifold fuel pressure -- repeat	17-Oct-96	19-Oct-96	Replaced fuse. Sys ops chd sat IAW TO 1H-130(H)H-2-6. Insufficient time toT/S further. Expect fuse will blow inflight
X	X	17-Oct-96	962915100	Fuel leak RT wing root above SPR panel	17-Oct-96	17-Oct-96	Tighten wiggins coupling leak check good IAW TO 1C-130(H)H-2-14
X	X	18-Oct-96	962925100	RT A/R pod FWD surge suppressor press reads "0"	20-Oct-96	21-Oct-96	Forward A/R supressor serviced to 45 psi @ 1400 on 10/19. Lk chk on 10/20 @ 1215 good reading 45 psi
X	X	24-Oct-96	962985166	#2 suction boost pump light intermittently stays on after pump is turned on. Light goes out after switch is cycled several times.	25-Oct-96	25-Oct-96	Adjusted light assembly ops check sys check good IAW 1C-130B-2-2
X	X	28-Oct-96	963025100	Left hand Benson tank bottom drain valve leaks	28-Oct-96	28-Oct-96	Replaced seal on valve, transferred 3000 lbs of fuel in tank, checked for leaks checked good IAW 1C-130(H)H-2-6
X		31-Oct-96	963055100	RT pod surge suppsor reads zero	31-Oct-96		Fwd surge suppressor serviced, performed 6 hr leak check, checks good IAW 1C-130(H)H-2-6
X	X	1-Nov-96	963065104	Fuel leak RT dump mast	1-Nov-96	1-Nov-96	Drain dump manifold cycled x-valve, pressurized with dump pump system, no leak noted after 15 min IAW TO 1C-130(H)H-2-6
X		6-Nov-96	963115101	RT A/R pod lwr surge supressor lost precharge	OPEN		
X	X	17-Nov-96	**963125201**	The left fuselage tank gauge on the A/R panel reads 600 lbs less than the gauge on the tank refuel gauge	20-Nov-96	20-Nov-96	Tank cal'd then ops checked good IAW 1C-130(H)H-2-6

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X	X	17-Nov-96	**963125202**	The right fuselage tank gauge on the A/R panel reads 1000 lbs less than the gauge on the tank refuel gauge	20-Nov-96	20-Nov-96	Tank cal'd then ops checked good IAW 1C-130(H)H-2-6
X		17-Nov-96	**963125204**	The left ext fuel quantity gauge has an aux fuel gauge installed and the right aux tank has an external fuel gauge installed	19-Nov-96		(No Doc # required - gages swapped) Installed proper indicators in each position. Awtg calibration until repair work on each tank is completed: (LT Ext - pg 2, blk 1; RT Aux - 781K, pg 3, JCN 953105101). Op ck/cal req IAW TO 1C-130(H)H-2-6. See pg 14, blk 3 and pg 15, blk 1 for op cks.
X		19-Nov-96	**963125204**	Cal/Op chk of LT Ext F/Q ind sys required after installation of new gauge (pg 9, blk 1) and system repair (pg 2, blk 1) IAW TO 1C-130(H)H-2-6	20-Nov-96		Ops ck not required due to in tank maint reqd. Tank inop pg 2-1
X		19-Nov-96	**963105101**	Cal/Op ck required on RT Aux F/Q ind after installation of proper gauge (pg 9, blk 1) and tank repair (781K, pg 3, JCN 953105101), IAW TO1C-130(H)H-2-6	20-Nov-96		No ops check required. Fuel tank is inop due to leakage of cavity drain. See 781K, pg 3.
X	X	20-Nov-96	963255103	RT A/R pod has fuel leaking from drouge	20-Nov-96	20-Nov-96	Pressurized RT A/R pod inspected. All fuel lines and couplings. Inspected drouge. Retorqued wiggins couplings. No leaks noted IAW 1C-130(H)H-2-14.
		22-Nov-96		Mishap			
INFO SOURCE		**DISCREP**	**EVENT-ID**	**WRITE-UPS FOR "OFF-EQUIPMENT" PROBLEMS**	**CORRECT**	**CORRECT**	**CORRECTIVE ACTION**
781s	**CAMS**	**DATE**			**DATE**	**DATE**	
	X	3-Jul-96	961855101	RT Aft surge suppressor will not hold pre-charge		9-Jul-96	Turnin to MSL
	X	28-Sep-96	962727231	RT A/R hose removed due to damage. Hyd line also damaged, C/B pulled.		7-Oct-96	Rivet drive shaft and local mfg hyd lines per sample
Note: JCN's in bold do not correspond to discovery dates or previous write-ups.							